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MICHIGAN STUDY OF USE OF ENGINEERS

How America can make better use of its scientists and engineers will be studied by The University of Michigan Institute for Social Research with a $67,000 grant from the Carnegie Corporation of New York.

Questionnaires and interviews with hundreds of scientists in business, government, and college work will examine scientists' working relations with their colleagues and supervisors, their motivations for work, their level of job interest and satisfaction, and measures of their technical performance.

The 18-month project will be co-directed by Rensis Likert and Donald Pelz. Senior associate will be S. Stewart West. It will supplement and extend research conducted in this area by the Institute since 1952.

DO YOU KNOW . . . .

► . . . . That "Applications of Economic Evaluation in Industry" is the theme of the two-day summer school in conjunction with the annual meeting—on June 13 and 14? Because of the "across the board" interest of all kinds of engineers in industry, the program has been called to the attention of other organizations, particularly those related to chemistry. The program is jointly sponsored by the Engineering Economy Division of ASEE and the Engineering Economy Research Committee of AIIE. For detailed information write to Professor G. J. Matchett, Director, National Center of Education and Research in Dynamic Equipment Policy, Illinois Institute of Technology.

► . . . . That the Engineers' Council for Professional Development has asked ASEE to make an evaluation study of technical institute education? This action was taken at the request of its Education and Accreditation Committee. The General Council of ASEE accepted the invitation at its meeting in November and authorized President Alexander to appoint an appropriate committee. The committee is to plan the study, seek financing and carry the project through to completion. The study is a logical follow-up of the National Survey of Technical Institute Education recently completed and for which copies of the final report will soon be available from the Office of the Secretary.

► . . . . That engineers lose their preferred salary positions over other groups between 5 and 10 years out of school? This is a conclusion of Dr. Frank S. Endicott, Director of Placement, Northwestern University. His figures for comparative average monthly salaries taken from NSPE's "Engineering Employment Practices," February 1959, are:

Field	Class of		
	1958	1953	1948
Engineering	480	651	806
Accounting	422	618	839
Sales	419	683	924
General Business	418	638	861

► . . . . That the committee to discuss research on "the education of engineers" has held two meetings? Representatives of ECRC, Educational Methods Division, and CDEF met with ECRC's Committee on Research Administration to get plans underway. ECRC does not wish to undertake such research, but primarily wants to encourage and stimulate all interested groups to develop and carry out programs. As a first step the membership of the Society is requested to submit to the chairman of the committee, Dr. H. W. Barlow, Director, Washington State Institute of Technology, Washington State College, Pullman, Washington, all information on projects being planned, underway, proposed, completed, etc. Do your part in aiding this committee in its challenging task. The committee will again meet during the annual meeting.

► . . . . That Dr. H. L. Hazen, electrical engineer, and Dean of the Graduate School of the Massachusetts Institute of Technology, has been named to the 12 member National Advisory Committee to assist the Office of Education in administering the graduate fellowship program under the National Defense Education Act for 1958? The committee has assisted U. S. Commissioner of Education Dr. L. G. Derthick in setting up criteria for approval and evaluation of the approximately 8,000 requests for fellowships embodied in about 1,000

programs. One hundred and sixty-six institutions submitted programs. The field of literature and deans of graduate schools dominate the committee.

► . . . . That 75,000 fellowship travel grants and other awards available in colleges and universities throughout the world are listed in the new tenth edition of UNESCO's "Study Abroad." Also listed are organizations in 50 countries which advise students on the problems involved in studying abroad. Copies may be obtained for $3.00 each from the UNESCO Publication Center, 801 Third Avenue, New York, New York. UNESCO also publishes "Teaching Abroad" which lists applications from teachers who wish to teach abroad and requests for teachers to fill specific posts available in various institutions throughout the world. The price of this publication is $1.00 per copy.

► . . . . That 33 schools have engineering technician programs accredited by ECPD? A total of 116 programs are offered.

► . . . . That honors programs are least found where they are most needed—in the professional schools that train young people for specialized careers in such fields as engineering . . . and medicine? This is the statement made by Dr. F. H. Harrington, Academic Vice President of the University of Wisconsin in the February 1959 issue of the Newsletter of the Inter-University Committee on the Superior Student. The gist of the article can be obtained from the following statements, essentially as in the original article. "Least often found" is a statement of fact. By and large the professional schools have lagged behind the arts and science colleges in this respect. By their very nature the professional courses put emphasis on training for specific careers. To give the ablest professional students something extra will require an additional effort. Hence, the thought that work is "most needed" here. Much of the effort will be wasted if emphasis is on more job training. Research-oriented programs should yield better results. But best of all will be programs deliberately designed to give the best students opportunities to broaden their intellectual horizons. The faculties of most professional schools are putting increased emphasis on fundamental theory, and will want to point their ablest students in that direction. Instead of giving more bread-and-butter training, they will want their young people to go further into mathematics or physics or social psychology or language. This, of course, will give the broader type of training which outstanding students deserve. Another trend will be toward directed group or individual research. The research experience may also turn the better student toward graduate work, and possibly toward a teaching career—a development most of us would favor. Our outstanding people, our future decision-makers, must learn to bring together the specialized contributions into meaningful over-all patterns. Programs for the ablest professional school students should build on maturity and on specialized professional knowledge.

► . . . . That five programs involving engineering were approved by NSF to enable high school teachers to get research experience during the summer of 1959? Of the five programs, one is only for engineering; one is engineering and physics, one is a combined program for biology, chemistry, and engineering; and two are for chemical engineering and chemistry. Of the 54 programs re-

ceiving grants (total of $800,000), 42 involve chemistry, 27 physics, and 23 biology.

► . . . . That the National Science Foundation's latest study of research and development in industry indicates that between 1954 and 1957 the number of employed engineers reported by industry increased by over 119,000? During the same period of time, engineering colleges of the United States graduated about 71,000 "first degree" engineers. Where do the other 40% of the newly employed engineers come from? Or, what is happening to the classification of jobs termed engineering?

► . . . . That definite action has been taken on organizing the Associacāa Brasileira de Professores de Engenharia? That means the Brazilian counterpart of ASEE. A constitution has been drafted, patterned after ASEE's, and by the time you are reading this JOURNAL the new association should be a matter of fact. Dr. S. S. Steinberg, President of the Instituto Technologico de Aeronautica at São Paulo, Brazil, has been instrumental in accomplishing the establishment of this association.

► . . . . That "Technical Translations" will be published twice a month by the U. S. Department of Commerce to provide a central source of information in the United States on translated technical literature available to science and industry? Publication is by the Office of Technical Services and was started in January. Subscription rates are $12.00 a year in the United States and $16.00 a year in foreign countries. Single copies sell for 60¢ each. Subscriptions should be sent to OTS, Washington 25, D. C. The Special Libraries Association's "Translation Monthly" is incorporated in the new publication.

► . . . . That at ASEE annual meetings about 13% of the presiding officers and 20% of those presenting papers are from non-educational institutions? Also, that about 1,200 individual members have similar affiliations? It is thus apparent that engineering education and industry are cooperating in almost all aspects of ASEE activities.

► . . . . That the Aeronautical Division has been spear-heading ASEE's efforts to have joint programs with other professional societies? For five or six years it has been participating with the Institute of Aeronautical Science in a joint meeting in January, and for the last two years had an additional joint meeting during the annual summer meeting. This year, because both societies have their Annual Meetings during the same week, a joint meeting will be held with the American Rocket Society during its summer meeting in San Diego. This is a very important development because engineering and space flight should not be permitted to have a gap develop between them, such as has existed since World War II between engineering education and nuclear energy. We should compliment the Aeronautical Division and wish them well in their newest venture.

► . . . . That the 1960 College-Industry Conference will be sponsored by Washington University in St. Louis? RWI also reports that the University of Cincinnati will host the 1961 meeting.

► . . . . That the long drawn-out negotiations regarding the separate accreditation of colleges of engineering by the State of New York has finally been settled? In the past, all colleges desiring registration in New York State had to fill out, for each curriculum, a questionnaire much

more complex than the one used by ECPD. Under the new arrangement ECPD will send a copy of its information to appropriate New York State officials and the decision of ECPD regarding accreditation will be given careful consideration as the basis for the registration of the curricula by the New York State Education Department. Since that department, by State law, is required to determine registration, it must reserve the right to obtain additional data if it is believed to be necessary. Dean E. C. Easton is chairman of the ECAC's Committee on Accreditation by Individual States, and he and his committee are to be complimented for their efforts to resolve the duplicate accreditation.

► . . . . That the 1959 meeting of ECPD will be on Monday and Tuesday, October 5 and 6, in Cleveland, Ohio? In subsequent years this meeting will be in Montreal, Atlanta or Louisville, Philadelphia, Chicago, and New York, 1960 to 1964 respectively.

► . . . . That EJC calls attention to a concern about the recognition given the engineer? At the current session of Congress many bills are being introduced which pertain to engineering and there will be much discussion regarding the aid to Science and "Technology." EJC suggests that from many points of view it would seem desirable that efforts should be made to change the terminology of "Science and Technology" to "Science and Engineering," that it could begin with the change in title of Dr. James R. Killian, Jr. to "Special Assistant to the President for Science and Engineering," and that his committee be called "The President's Science and Engineering Advisory Committee." Another problem in terminology arises as a result of the National Defense Education Act for 1958, Title 8, Vocational Education programs, which HEW interprets as the support of a wide range of programs including the training of engineering technicians. The legislation uses terminology of "less than college level," whereas the engineering profession, and particularly ECPD and ASEE, have maintained that the engineering technician program is of college level, the two year program type. HEW apparently is expecting the state educational authorities to define the scope of activity for which the state desires federal support.

► . . . . That as of the first of the year a grant of federal funds for vocational education programs in 14 states has been approved? In addition, plans from 19 other states for programs under the National Defense Education Act for 1958 are being reviewed by the U. S. Office of Education. A fund of 3.25 million dollars is available for the current fiscal year to get the program underway. The largest of the first 14 grants was $170,450 for California.

► . . . . That your plans to attend the annual meeting in Pittsburgh should be made by now? You have received the preliminary program and pre-registration and housing cards. Send them in now! Pitt and Carnegie Tech are about ready for you, and Pittsburgh, celebrating its bicentennial, has its arms open. A significant change in the program is a full day at a research laboratory! Still another feature is devoting the Monday General Session to a program on some of the new developments influencing engineering education instead of the traditional committee reports. Don't forget June 15–19 in Pittsburgh, Pennsylvania.

W. Leighton Collins
Secretary

WOULD ENGINEERING STUDENTS BE TEACHERS?

A Survey of Student Views

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Summary

In May, 1958, high scholarship undergraduate students and graduate students in engineering at Purdue University were surveyed regarding two experimental programs which were under consideration by ASEE. These two programs would provide for:

(1) a student subscription plan to the JOURNAL at $1.50 per year (Program A),

(2) a discussion group on engineering teaching to be organized informally at interested engineering institutions (Program B).

These programs would be intended to encourage promising engineering students to consider engineering teaching as a career.

The students in this study were also asked to indicate the amount of consideration they had previously given engineering teaching and to indicate their frank views of the advantages and disadvantages of an educational career.

Approximately 40 per cent of the students returned questionnaires and the results are as follows:

1. A substantial percentage (28%) indicated a definite interest in the two experimental programs. Only a small percentage (8–11%) indicated that they were definitely not interested in either program.

2. Personal satisfaction, opportunity to conduct research, and academic atmosphere were most often cited as advantages of engineering teaching as a career.

3. Salary, slow advancement, and repetition (too much clerical work) were most often cited as the disadvantages of engineering teaching as a career.

4. About 10 per cent of these select students were planning on engineering teaching as a career.

5. About one-fourth of the respondents indicated that they had given an engineering teaching career considerable consideration. Less than 10 per cent indicated that they had never considered engineering teaching as a career.

6. Important differences were noted between the views and plans of graduate students and undergraduate students regarding engineering careers in teaching.

Background for the Study

Potential increasing enrollments, recent shortages of qualified engineering teachers, and the increasing importance of graduate work have resulted in considerable interest among

Program A

1. The JOURNAL OF ENGINEERING EDUCATION is a periodical published by the American Society for Engineering Education 10 times a year. It contains articles on such topics as engineering curricula, science and engineering, new developments in engineering education, etc. The American Society for Engineering Education is making the JOURNAL OF ENGINEERING EDUCATION available to undergraduate and graduate students at $1.50 (usual price $10.00/yr.). The copies would be sent to a faculty representative for local distribution.

Indicate below whether or not you are interested in Program A	Total	Grad. or Undergrad.		Classification				Post Degree Plans			Amt. of Consideration Given to Teaching			
	To	U	G	Jr	Sr	MS	PhD	I	Te	O	C	S	L	N
a. I would definitely be interested	28	22	33	25	21	27	46	22	60	27	53	29	15	0
b. I would possibly be interested	34	45	25	47	43	25	24	39	20	33	26	39	42	25
c. I would probably not be interested	23	24	23	20	27	29	12	24	8	27	10	25	29	37
d. I definitely would not be interested	11	9	14	8	9	16	10	12	4	12	5	7	14	33

Program B

2. Undergraduate and graduate students in engineering should be given an opportunity to discuss engineering education problems including curriculum, teaching, career opportunities in engineering teaching, etc. Small discussion groups are being organized at engineering colleges and universities to discuss contemporary problems in engineering education.

Indicate below whether or not you would be interested in such a program if offered at Purdue	Total	Grad. or Undergrad.		Classification				Post Degree Plans			Amt. of Consideration Given to Teaching			
	To	U	G	Jr	Sr	MS	PhD	I	Te	O	C	S	L	N
a. I would definitely be interested	28	28	27	35	22	23	34	22	48	28	48	26	18	8
b. I might be interested	38	47	31	35	55	29	37	44	28	35	35	51	38	17
c. I probably would not be interested	20	17	24	22	13	27	20	21	12	22	11	17	29	33
d. I definitely would not be interested	12	9	15	8	9	20	5	11	4	16	3	5	15	42
3. If interested, how often would you recommend meeting?														
a. Every two weeks	7	8	6	8	8	8	0	8	0	7	6	9	7	0
b. Monthly	46	52	42	53	51	37	51	47	48	46	66	49	36	29
c. Once a semester	8	10	6	14	8	2	12	8	12	6	6	8	12	0
d. Other	6	8	4	2	12	2	7	5	8	6	5	9	4	4
e. Blank	34	22	43	22	22	49	29	31	32	35	16	25	41	67

Program B—*Continued*

Indicate below whether or not you would be interested in such a program if offered at Purdue	Total	Grad. or Undergrad.		Classification				Post Degree Plans			Amt. of Consideration Given to Teaching			
	To	U	G	Jr	Sr	MS	PhD	I	Te	O	C	S	L	N
4. At what time would it be most convenient for you to meet														
a. Monday	10	13	7	10	15	57	7	13	4	8	8	14	11	0
Tuesday	14	18	10	12	22	7	10	12	12	17	15	14	14	12
Wednesday	18	23	13	33	16	10	12	17	24	18	23	17	18	12
Thursday	13	14	13	8	18	13	12	11	12	17	15	20	11	0
Friday	5	4	6	6	3	13	5	6	0	6	5	8	5	0
Saturday	4	6	2	6	6	7	0	7	0	2	0	7	5	0
Blank	62	36	60	39	34	2	66	43	60	48	48	39	47	75
b. Luncheon	14	9	19	12	6	12	32	11	16	15	24	18	3	8
Late afternoon	21	22	21	16	25	18	27	20	24	20	31	27	15	0
Evening	37	53	23	59	49	22	24	43	28	34	34	39	47	21
Other	1	.87	1	2	0	0	2	0	0	2	2	1	0	0
Blank	36	25	44	27	24	49	34	31	40	39	24	22	42	71
5. What topics would you like to see discussed?														
a. Responded	48	57	41	59	55	39	46	52	52	47	56	62	41	17
b. Did not respond	52	43	59	41	45	61	54	48	48	53	44	38	59	83
6. Check your classification below														
a. Undergraduate student—Junior	20	42	0	100	0	0	0	18	0	28	5	18	33	33
b. Undergraduate student—Senior	27	58	0	0	100	0	0	35	4	28	8	39	34	29
c. Graduate student—M.S. candidate	34	0	67	0	0	100	0	37	28	34	37	34	32	33
d. Graduate student—Ph.D. candidate	17	0	33	0	0	0	100	9	68	9	50	9	1	0
e. Other	2	0	0	0	0	0	0	0	0	1	0	0	0	4

Program B—*Continued*

Indicate below whether or not you would be interested in such a program if offered at Purdue	Total	Grad. or Undergrad.		Classification				Post Degree Plans			Amt. of Consideration Given to Teaching			
	To	U	G	Jr	Sr	MS	PhD	I	Te	O	C	S	L	N
7. Indicate your major field (ME, EE)														
a. AE	13	22	6	31	15	4	0	19	0	12	8	17	10	29
b. AgE	3	.87	6	0	2	9	7	1	8	4	6	3	3	0
c. ChE	10	17	3	14	19	5	7	10	0	13	2	13	14	12
d. CE	10	5	15	4	6	1	7	8	12	12	6	8	14	17
e. EE	18	14	22	18	10	19	37	13	40	17	27	12	18	4
f. ES	7	8	15	12	4	15	7	8	8	15	11	9	12	12
g. IE	3	.87	5	0	2	18	2	2	12	2	6	4	0	0
h. ME	26	30	23	16	4	6	24	33	12	23	24	34	26	17
i. MtE	2	3	2	4	2	23	2	3	4	1	3	1	3	0
j. Other	2	0	5	0	0	6	5	3	4	3	5	0	1	8
8. What are your plans immediately after completing your requirements for your degree?														
a. Engineering in industry	45	50	42	41	57	49	27	100	12*	7*	29	46	60	54
b. Engineering teaching	11	2	19	0	3	8	41	12*	88*	4	35	4	0	0
c. Other	45	48	39	59	41	42	32	7*	0	89	31	48	39	46
9. Have you ever considered engineering teaching as a career?														
a. Have given considerable consideration	26	7	44	6	8	29	76	14	92	21	100	1*	0	0
b. Have given it some consideration	31	38	26	29	45	31	17	33	4	37	0	99	0	0
c. Have given it little consideration	30	42	19	49	37	28	2	40	0	29	0	0	100	0
d. Have never considered it	9	13	6	16	10	10	0	12	0	11	0	0	0	100

Program B—*Continued*

Indicate below whether or not you would be interested in such a program if offered at Purdue	Total	Grad. or Undergrad.		Classification				Post Degree Plans			Amt. of Consideration Given to Teaching			
	To	U	G	Jr	Sr	MS	PhD	I	Te	O	C	S	L	N
10. What advantages, if any, do you think there are to a career in engineering teaching?														
a. Responded	81	87	79	86	88	77	83	82	88	83	92	86	78	71
b. Did not respond	19	13	21	14	12	23	17	18	12	17	8	14	22	29
11. What disadvantages, if any, do you think there are to a career in engineering teaching?														
a. Responded	80	90	74	90	90	71	80	81	88	82	89	85	78	71
b. Did not respond	20	10	26	10	10	30	20	19	12	18	11	16	23	29
12. Do you hold a staff appointment at Purdue?														
a. Yes, undergraduate teaching appointment	3	5	1	0	9	0	2	5	0	2	3	3	3	4
b. Yes, graduate teaching appointment	12	0	23	0	0	21	29	10	32	6	32	5	4	4
c. Yes, graduate research appointment	12	1	23	0	2	22	24	9	16	14	19	14	7	4
d. Other	70	94	53	100	90	58	44	75	52	78	46	78	86	87

* Multiple responses given by some individuals

educators in the recruitment of engineering teachers for the future. At the 1957 Annual Meeting of ASEE, Professor P. L. Balise of the University of Washington proposed that the JOURNAL be made available to engineering students at a nominal cost. In addition, it was suggested that groups be organized to discuss contemporary engineering education programs. The long range view was to determine the feasibility of setting up student branches of ASEE. This activity was endorsed by the Committee of Young Engineering Teachers and the Secretary of the ASEE, Professor Leighton Collins, in view of its potential for future faculty recruitment. Purdue University was one of the institutions selected to determine the amount of interest that there might be in this type of activity, and this report is concerned with results of the Purdue survey.

Procedure

To determine the views of engineering students regarding these programs a short questionnaire was sent to a select group of undergraduate students, viz., members and prospective members of Tau Beta Pi (honorary all-engineering fraternity). In addition, graduate students in engineering who did not hold full time academic appointments were also sent questionnaires.

There were 245 replies which represent 38 per cent of the group to whom questionnaires were sent. (No follow-up was made of non-respondents.) The questionnaire was broken down as follows:

1. total group response,
2. undergraduates and graduates,
3. juniors, seniors, M.S., and Ph.D. candidates,
4. plans after receiving degrees (industry, teaching and other),
5. amount of consideration previously given to engineering teaching (considerable, much, some, little).

A copy of the questions with the percentage response to each question is given in Appendix A.

Results

Approximately one student in four was definitely interested in Program A (the $1.50 per year subscription plan to the JOURNAL). One in three graduate students, and one in five undergraduate students expressed a definite interest in the student subscription plan. About one-half of those who had given engineering teaching extensive consideration were definitely interested. Only eleven per cent of those surveyed indicated that they were definitely not interested in the student subscription plan.

For Program B (the discussion group) approximately one student in four indicated a definite interest. As might be expected, approximately one-half of those planning on engineering teaching were definitely interested in the discussion program as contrasted with about one-fourth of those who planned to go into industry or who had other plans (graduate work, military service, etc.). Forty-eight per cent of those who had given considerable consideration to teaching were definitely interested. Less than one student in ten was definitely not interested in the discussion program on engineering education topics.

Of those that were interested in a discussion group, the majority (46%) preferred a monthly meeting rather than once a semester (8%) or biweekly (10%) meetings. Over half of the undergraduates preferred evening meetings, but the graduates were about equally divided between luncheon, late afternoon and evening meetings.

TABLE I

FREQUENCY OF SUGGESTED TOPICS FOR DISCUSSION IN PROGRAM B

Topic	Frequency		
	Undergraduates	Graduates	Total
1. Engineering Curricula	27	17	44
2. Teaching Methods	12	15	27
3. Teaching Opportunities	11	13	24
4. Grading, Testing, and Standards	5	7	12
5. Specialization vs. Theory (art vs. science)	6	5	11
6. Student-Teacher Relations	5	4	9
7. Non-technical courses	5	1	6
8. Teacher Recruitment & Requirements	1	4	5
9. Teaching Standards and Supervision	4	1	5
10. Four year vs. Five year Program	1	3	4
11. High school Preparation	4	0	4
12. Professional Engineering Problems	0	4	4
13. Engineering Research	0	4	4
14. Guidance and Counseling	3	1	4
15. Teaching vs. Industry	1	2	3
16. Education Problems	1	2	3

About one-half of the students listed topics for discussion and these are classified in Table I. Table I reveals that the most frequent interests were engineering curricula, teaching methods, teaching opportunities and grading.

In one question inquiry was made as to students' post degree plans. Some interesting differences resulted with respect to engineering teaching. Most of those who were planning to go into engineering teaching were graduate students, usually Ph.D. candidates. Most of those planning to go into industry were undergraduates or M.S. candidates and had given little or no consideration to engineering teaching as a career. Only seven per cent of the undergraduates had seriously considered teaching as contrasted to 29 per cent of the M.S. candidates and 76 per cent of the Ph.D. candidates. Less than ten per

TABLE II

A SUMMARY IN PER CENT OF THE ADVANTAGES OF ENGINEERING TEACHING AS A CAREER

Type of Comment	Total Classification					Plans After Degree			Consid. of Teaching		
	Total	UG	G	MS	PhD	Indst.	Tchg.	Other	Much	Some	Little or None
Personal Satisfaction	17	16	17	13	24	19	32	11	30	17	10
Opp. to Conduct Research	13	14	12	12	12	15	8	13	11	9	19
Prestige & Social Position	6	8	4	4	5	5	4	8	6	5	7
Academic Atmosphere	14	12	14	10	24	19	20	10	24	13	10
Security	10	12	8	10	5	16	4	6	3	4	19
Easy Work	2	4	1	0	2	3	4	2	2	1	4
Freedom of Activities	17	16	16	12	24	20	24	15	19	25	10
Opp. for Learning	12	9	14	16	10	13	16	11	18	17	8
None or Blank	20	21	19	19	17	23	12	20	11	20	27

Percentages were based on the total number of people in each classification and may total more than 100% because of multiple response.

TABLE III

A Summary in Per Cent of the Comments on the Disadvantages of Teaching

Type of Comment	Total Classification					Plans After Degree			Consid. of Teaching		
	Total	UG	G	MS	PhD	Indst.	Tchg.	Other	Much	Some	Little or None
Salary	63	75	51	51	68	71	64	60	71	62	61
Lack of Time	4	4	3	3	7	5	4	3	5	4	3
Slow Advancement	11	15	61	6	5	13	4	11	11	7	14
Repetitions (too much clerical work)	10	11	7	7	0	14	4	6	2	14	10
Tend to be too Theoretical	6	4	6	6	5	9	8	2	6	8	3
Need too Much Education	6	8	3	3	2	8	4	6	3	3	10
Lack of Academic Freedom	*	1	0	0	0	0	0	0	0	0	0
Politics	1	0	3	3	2	0	0	0	0	0	0
None or Blank	22	16	27	27	24	30	12	18	19	18	27

* Less than ½ of 1%.

cent of those surveyed had never considered teaching.

To obtain further insight into their views they were asked to indicate their opinions with regard to the advantages and disadvantages of engineering teaching; the results are summarized in Table II and Table III respectively.

Examination of the advantages of engineering teaching as summarized in Table II indicates that personal satisfaction, freedom of activities, academic atmosphere, and opportunity to conduct research were most frequently mentioned as advantages of engineering teaching as a career, whereas salary, slow advancement, and repetition (too much clerical work) seem to be principal disadvantages in the views of the engineering students surveyed. Some group differences might also be noted. Personal satisfaction was cited by 24 per cent of the Ph.D. candidates, 32 per cent of those planning to enter teaching, and 30 per cent of those that had given considerable consideration to teaching as a career. As shown in Table III, undergraduates more frequently cited salary, repetitiousness and slow advancement as disadvantages.

Conclusion

On the basis of questionnaire results the following observations seemed pertinent: 1. A substantial number of the high scholarship students in engineering were interested in the two ASEE experimental programs. 2. Suggested topics for discussion groups were engineering curricula, opportunities in engineering teaching, and teaching methods. 3. A substantial number of the highly qualified students considered teaching as a career but few gave extensive consideration. 4. Few of the undergraduates and master's degree candidates planned on engineering teaching at this stage in their careers; however, a substantial number of the Ph.D. candidates did plan to teach. 5. Since salary and slow advancement were most often cited as the disadvantages by the gifted students it behooves engineering educators to examine the basis for student opinions. 6. Since personal satisfaction, academic atmosphere and freedom of activities are viewed as the primary advantages of teaching, it also behooves engineering education to examine these factors as potential bases for the retention and recruitment of future engineering faculties.

(*Continued on page 796*)

ENGINEERING EDUCATION IN INDIA

N. W. DOUGHERTY

Dean Emeritus of Engineering,
University of Tennessee

Dean Emeritus N. W. Daugherty was Deputy Director of the ASEE Engineering Education Mission to India. ASEE contracted with the International Cooperation Administration of the U. S. State Department to send a mission to India for eight weeks to make a feasibility study for the establishment of an institute of technology at Kanpur. After an extensive tour of many Indian schools, a report was prepared, which is the property of the Government of India, and thus cannot be published without its permission. But since it was believed the members of ASEE would like to be informed about the nature of engineering education in India as it is at the present time, Dean Dougherty was asked to prepare this article.

Engineering education in India is growing out of a long British tradition, though it is being garnished with an emphasis of its own. Industry has had a negative influence in that lack of production has reduced the need for engineers to a very minimum. "With the ascendency of the British in India, however, various restrictions were imposed. Cotton fabrics of Indian origin were denied entry into British markets by law, and even at home their manufacture was discouraged. Consequently, these industries suffered rapid decay. As a result of large-scale imports of British manufactured goods, Indian artisans were thrown out of employment and India progressively became an agricultural outpost of the industrial economy of Britain." [1] This is shown by the frugal development of engineering in the colleges of India. There were only 2,900 students registered in engineering in 1947 and approximately 6,000 are registered today.

For many years the educational system has been bedeviled by the tradition of the liberal arts, which was the training for government employees. Many good students graduated from this program to become "educated unemployed" because there were not enough government jobs to go around. Methods of teaching and programs of study have also followed the pattern. The lecture system, the tutorial system and the attitude toward books stem from this same tradition.

Today science and engineering are finding a place of their own. "The Second Plan allocates to university education nearly four times as much as did the First Plan. Most of it will go to improve and expand technical and scientific education in the universities, to fill the pressing demands for skilled and trained personnel for developing the nation." [2] Work in industry is becoming as dignified as work in government, though the government employee still has a place of high esteem. "The prejudices and obstacles against industrial employment are steadily overcome." [3] This attitude takes an American back to the days when science and engineering were fighting a battle in his own colleges. There was a day when edu-

[1] *Facts About India*, The Publications Division, Ministry of Information & Broadcasting, Government of India.

[2] *The New India, Progress Through Democracy*, Planning Commission, Government of India.

[3] *Report of the Engineering Personnel Committee*, The Macmillan Company, Government of India, Planning Commission.

cators looked askance at departures from ancient languages and philosophy. The Land Grant Act (1862) was not a Magna Charta for sciences and engineering, but it was their declaration of independence and equality. In the hundred years since that time science and technology have asserted their values alongside those of the languages and literature, and they have climbed to a place of respectability in the educational scheme.

Almost within a day, certainly within a decade, science and technology have found a place of esteem in Indian education. Applicants for admission to the engineering colleges are numbered by the thousands and admissions are numbered by the hundreds.

Other long traditions are having their influence. Chester Bowles, in an Ambassador's Report, suggests that there is a line of descent from Plato and Aristotle today. Certainly some attitudes are much more ancient than we find in modern England or in the tradition of Edison or Kettering. Aristotle believed in contemplation rather than experiment, or the use of the hands. A young American adviser at Bakra Nagal Dam said that his greatest criticism of Indian engineers was their unwillingness to use their hands or to take individual responsibility. They, of course, have not had a long tradition of machinery, automobiles, electric wiring or radio, which are the common heritages of American boys.

Early Engineering Colleges

Engineering education began in France during the last quarter of the eighteenth century, in America during the first quarter of the nineteenth, and in India about the same time. By the middle of the century America recognized some half dozen degree-granting schools in engineering, while in India there were at least two such schools. Roorkee in the North was founded in 1847 and Guindy in the South began instruction in civil engineering in 1857. Some instruction in surveying had been given at Guindy many years earlier in 1794, but it appears that the work was intermittent and that engineering was begun at the later date.

There is a close relation between industrial production and the need for engineering graduates. To stop the one is to stifle the other. Since industrial production was not fostered under British rule, we would expect the engineering schools to mark time and produce a limited number of engineers.

Since Independence in 1947, there has been a greater effort to increase the instruction in science and engineering. In 1948 the Sarker Report was issued which recommended an increase in the number of students in the present schools and a further increase in the number of engineering schools. Some of the new schools were to be state supported, but the major innovation was the recommendation that there be four institutes of technology supported by the Central Government. They were to be located in the four grand divisions of India, one in the north at Kanpur, one in the east at Calcutta, one in the south at Madras and one in the west at Bombay. The one near Calcutta, at Kharagpur, is in full operation, the one at Bombay has begun instruction in temporary quarters while the other two are still in the planning stage.

Outside Influences

When American engineering schools declared their independence from the arts tradition, they did it in full measure. They have carried to such an extreme that members of the faculty

Façade of the new building of the India Institute of Technology, Kharagpur, India.

feel that they are supreme in their classrooms. Not so the Indian tradition. It has followed more closely that of Cambridge, or other English schools, which allows a student to study at one school and graduate at another. The parent institution gives an examination and persons who are admitted and who pass the examination are graduated at the umbrella school. For example, Guindy, one of the oldest of the engineering colleges, gives the examinations of the University of Madras, and its students who satisfactorily complete the examination are graduated from Madras.

In addition, the states assume control by preparing examinations for the schools in the state. Some one suggested that the relation is a bit like the University of the State of New York, which does no teaching, but which has some influence in the affairs of state-supported schools. In India, the students who graduate take and pass the state examination.

Another long-standing policy which has had its effect is the civil service list. To be eligible for many jobs, a person must have graduated from one of the universities. And to be employed by government was one of the highest of positions.

Before taking a look at the study of engineering, let us take a glance at the general economy. The major occupation is agriculture, which furnishes employment, such as it is, for 90 per cent of the population. Since the farms are small, there is not enough work to be done to keep a worker busy more than 100 days during the year. Industry is in the offing. Already a big start has been made, but much planning is to be done. Government and the private sector are making inroads into steel, power, irrigation, engineering industries, etc. As the program goes forward, there will be a much greater need for engineers than today, and today there is practically no unemployment among the engineers.

Hundreds of students have gone to the West for education and training. Their return and the use of Western

methods and equipment will have a major influence on the economy of the future. India realizes, however, that Western methods cannot be pulled up and transplanted without change; they must go through the mill of Indian culture.

Inner Workings

Instead of the College Board examinations now common in certain parts of the United States or high school graduation required in all the states, India uses an examination given by the states. Credits are transferable to each of the states, thus providing a general criterion for college entrance. Some of the secondary schools have ten grades, some eleven and a few have twelve grades. The program is to raise all of them to twelve as soon as possible. A graduate from a school with twelve grades may get admission to an engineering college, but usually the secondary school program is supplemented by two years of college science. Entering students, therefore, present the results of the secondary school examination plus examination in intermediate science. There is a published syllabus for examinations in grades 9 to 12, and another for the intermediate science.

Applicants made eligible by satisfactorily passing these examinations apply to the schools for admission. Sometimes there are quotas for certain geographical areas, but most often the committtee on admission selects students with the best records. Usually the parent or guardian must certify that the applicant has resources sufficient to pay expenses of a college course.

When a student is admitted to a course of study he must continue that course to graduation. There is practically no transfer between colleges, and very little transfer within the college. Usually the number of seats in civil, electrical, mechanical or any other major field of engineering is fixed and all are filled at first admission. Should a student drop out of school for any reason, there will be a vacancy in the classroom as well as in the hostel, or dormitory. Usually engineering students live in hostels, even though the college be located in his home town.

The American visitor will note a number of differences from his school or the one his boy or neighbor's boy is attending. His first reaction will be that major changes should be made to achieve similarity to his own American school. However, if he looks carefully he will find reasons for methods and programs as they are.

As he goes through the laboratories he will note that there is a wood shop, a pattern shop, an electric shop, a foundry, a machine shop and possibly a tin shop. If he graduated years ago he will remember the days of his overalls and his work in the shops; if he graduated a few years ago, he will have had no experience in any of these laboratories, except the machine shop, where his instruction was directed toward operations rather than mechanical skills.

Indian schools are continuing the shops because of the lack of mechanical skills of their students. No one has had an opportunity to take an automobile apart and put it back together again, no one has fixed the electric appliances, or mended the radio; all this is new and somewhat against the general tradition opposing the use of the hands. Shops are therefore used to get some skill, and to give some experience in the use of the hands.

To an American who has been nurtured on textbooks from the grammar grades, the complete lack of textbooks is astounding. The reason is

not hard to find. Examinations are given by the state or the parent university of which the engineering college is a part. Study, therefore, becomes a preparation for the examination and not study of courses in fluid mechanics, thermodynamics or mechanics. These are a part of the general syllabus, but not subjects in themselves. Lectures and the study periods are slanted to the general examinations. No textbook fits the syllabus. Some of the engineering college catalogues are but a reprint of the syllabus of the examination.

For some years Americans have been talking about the virtues of a comprehensive examination. Here is one with a vengeance. It may be given at the end of the first year, another at the end of the second year and one for graduation, or indeed at the end of the third year and then at graduation. Whenever it is given, it it the one that counts. American instructors in India report that students may cut classes before the general examination in order that they may intensify their preparation. They study their notes, they study old examinations, and of course they review the syllabus which takes the place of a curriculum.

Another surprise to Americans is that engineering schools should be small. Illinois Tech and Purdue would come under the ban because of their size. The usual reason offered is that students should have intimate contact with their professors in a sort of "know everybody" attitude. In America there is no special effort made for any one person to know all the students in school. With reasonable ratio of faculty to student there will be some member of the faculty available for as close a contact as may be had in a small school. Personal discipleship will probably not be as prevalent as it is in the small college where there is no multiplicity of faculty interests.

Another surprise is the number of faculty-student contact hours. They may run from 33 to 39 per week, made up of lectures, laboratories, tutoring and organized study. There is some scheduled time for recreation and some time is set aside for student study on their own. However, there is little of essay writing or problem solving as is common in U.S. practice.

In the United States, there is respect for professors who deserve it, but nothing of the jumping to attention and saluting which is prevalent in the Indian school. The custom is probably due to a long tradition of honoring their "betters" and to a natural politeness of the people. As long as a professor, or anybody, deserves respect he will get it, but if he throws it away the result may be devastating. If the Indian believes he is being slighted, or some one is taking advantage of him, he will resent it deeply, and his reaction may be silence or resistance by not doing. If the offense is real, he and his friends may take summary action.

Articulation with Industry

The engineer is finding his place in industry and government; the place in government is of long standing; that in industry is just being developed because of modest growth in industry. There is no scurrying to the colleges to employ the graduates of the next class. The utilities, the railroads, irrigation and much of the industry are owned by the government, thus recruiting at the colleges would be government competing against itself. Graduates make application for employment and, after a time, they receive it.

There is little industrial training for college graduates, though this activity has had its beginning. At the Tata

Steel Works there were classes conducted for beginning graduate engineers as well as for persons who were entering the skilled trades.

There is, of course, opportunity for education-industry cooperation in the fields of teaching, research, consultation and the award of scholarships. However, these areas are for future development. Since industry and education are government functions, a different type of cooperation from that which is known in America may be required. It would seem that two of the most promising fields are cooperative education for students and consulting services for the faculties.

The last comparison has all the elements of the American problem. There is a shortage of faculty in practically every engineering school; usually it is about 33 per cent. All American engineering colleges are facing the same shortage, and the reasons are about the same: better salaries in industry and government, more education needed for promotion, and the general tardiness of promotion. Teaching, as yet, has not achieved the status of working for government.

Conclusion

India has been subject to waves of depression and prosperity; in addition, the economy has been subject to outside pressures. However, the leaders are looking at their problems with determination and imagination. They have completed one Five Year Plan, and they are in the middle of a second. Real progress has been achieved and more progress is expected.

New education will probably make many changes in the present methods, but the final outcome will have the earmarks of India. When an American looks at their engineering instruction, he is frustrated that there are no text books, that examinations are out of the hands of the faculty, that the faculty do little or no consulting, and that the teaching is slanted to an outside examination rather than to special subject matter. Some of these things will probably change a bit, but Indians will probably continue the attitude of my English friend who said: "You teach too much. We have produced some good engineers by another method."

TEACHING AWARD AT STEVENS INSTITUTE

An annual award for honoring faculty members at Stevens Institute of Technology for outstanding teaching has been established by the Walter Freygang Foundation. The award, which consists of $1,000, will be given each year to a full-time member of the Stevens faculty who has "contributed substantially to the educational objectives of the college." Recipients will be selected primarily for their performance as teachers, though their contributions in related areas such as research and the publishing of technical papers will also be considered.

RUSSIAN ENGINEERING EDUCATORS

Five Russian engineering educators visited the United States for three weeks in January and February as the Soviet half of the Exchange Mission on Engineering Education. The Mission was sponsored by ASEE, with the cooperation of the U. S. Department of State and Engineers' Council for Professional Development, and with financial support from the National Science Foundation. Under the American half of the exchange, eight American engineering professors visited in Russia last November and December. The final report of that group is on page 837.

The Soviet visitors' itinerary included Yale University, Massachusetts Institute of Technology, Northeastern University, the University of California at Berkeley and at Los Angeles, Stanford University, California Institute of Technology, and the University of Illinois. Members of the Soviet delegation were Professor P. D. Lebedev, delegation leader and Chief, Main Administrator for Technical and Machine Building, Higher Technical Schools of the U.S.S.R., Ministry of Higher Education; Professor N. P. Bogoroditskii, Director of the Leningrad Electrical Engineering Institute; Professor K. M. Barshauskas, Director of the Kaunas Polytechnic Institute; Professor V. I. Atroshchenko, Deputy Director, Kharkov Polytechnic Institute, and Professor A. B. Davankov, Lecturer at the Mendileev Institute of

At M.I.T. the Russian delegation visited the school's nuclear reactor. Shown left to right are Charles L. Larson, Research Assistant in Nuclear Engineering, M.I.T.; Miss Natalie Kushnir, State Department interpreter; Professor Manson Benedict, head of the Department of Nuclear Engineering, M.I.T.; Professor Atroschenko; Dr. Leon Trilling, Assistant Professor of Aeronautical Engineering, M.I.T.; Professor Davankov; Professor Lebedev; Professor Barshauskas; and Professor Bogoroditskii.

Chemical Technology, Moscow. Mr. Francis B. Stevens, formerly director of the Office of Eastern European Affairs for the State Department, acted as tour leader.

A final report of their observations is not available as yet from the Soviet visitors, but we have gleaned a few observations from their press conferences. Unfortunately, a high proportion of the questions asked the Russians by the press concerned engineering education in Russian schools, a subject more adequately covered in the report of our mission to Russia and elsewhere, but the Soviet visitors did have some interesting things to say about our system as it appeared to them.

In comparing the laboratory facilities with those in Russian engineering schools, the visitors observed that the equipment was comparable in quality but that there was more space per student in schools in the United States. Another comparison that seemed to interest them was in the grouping of fields of study at each school. In the United States, they commented, an engineering school seems to put most emphasis on those fields of engineering of greatest economic importance to the part of the country in which the school is located. In the U.S.S.R., they said, more specialties are grouped at each school, regardless of the needs of the particular region in which it is located. Professor Lebedev, the leader of the group, commented that the U.S.S.R. is presently trying to move in the direction of decentralization and of consideration of the economic needs of the region, as in the United States.

Academic Freedom

Perhaps the most important difference observed by the Russian educators was the greater freedom of action open to college educators in America in the organization and teaching of their courses. According to Professor Lebedev, the U.S.S.R. hopes to expand such freedom in Russian institutions soon.

Asked about the benefits of the exchange mission, Professor Lebedev named several. The United States and the U.S.S.R. are working in the same branches of science and such an exchange as this saves time in research and increases mutual understanding among the scientists of the two countries. He also indicated that the visit would guide the Soviet government in the future in sending graduate students to the United States to study. He said that at present there are 10 graduate engineering students from Russia studying in the United States and that it is now felt that they would have gone to different institutions if the experience of this exchange group had been available at the time of their placement. In this connection he favored an extensive program of exchange of engineering graduate students between our two countries.

Professor Lebedev tentatively agreed to furnish ASEE with his report of the Russian visit to this country when it is published in the U.S.S.R. When it becomes available, it will be published in the JOURNAL.

ASEE ANNUAL MEETING

PITTSBURGH, JUNE 15–19, 1959

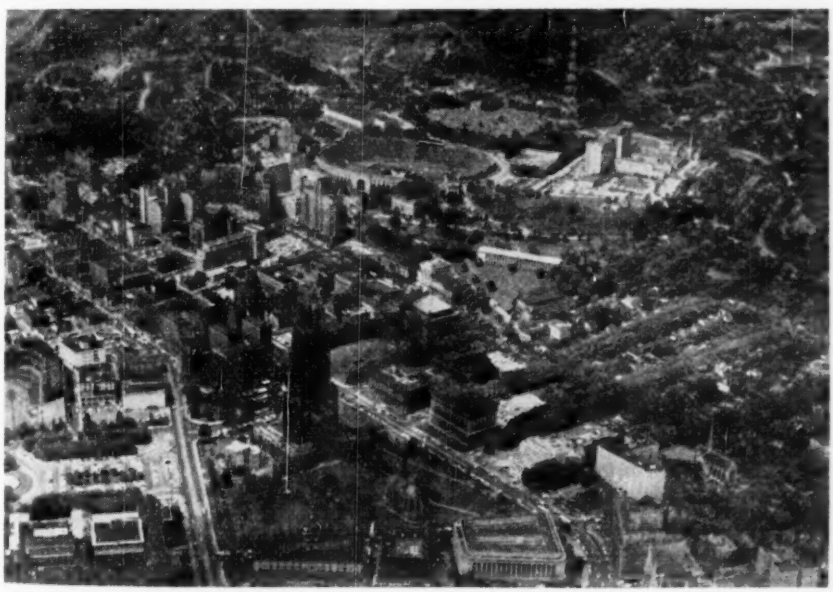
UNIVERSITY OF PITTSBURGH CO-HOST FOR 1959 ASEE ANNUAL MEETING

Visitors who come to the new Pittsburgh in this time of civic renaissance will find the sense of growth and change nowhere more electric than in the city's cultural center of Oakland. For in Oakland you will see the University of Pittsburgh deep in the process of developing into one of the great institutions of higher learning in the country.

Much has already been accomplished, and what has been done and what will be done at the University will help to bring additional strength and meaning to the region's renaissance. Already the University is the recipient of one of the most significant grants for the basic disciplines in our time—a gift of twelve million dollars from the A. W. Mellon Educational and Charitable Trust—for professorships in the natural sciences, humanities, and social sciences. This multi-purpose grant will enable the University to welcome to its educational circle some of the finest faculty and student minds in the world.

The University's academic development also necessitates a balanced physical expansion, one purpose of which is an undivided campus. This aspect of the long-range plan has been marked by purchases of nearby plots of land which will be used eventually for the construction of educational and dormitory buildings.

The University's history dates from 1787, the same year that Pennsylvania was admitted to the Union. Even on the modern campus the ghost of that time is still very much present; it is there in the core of liberal arts and sciences which continues today as the pure force behind all professional study.

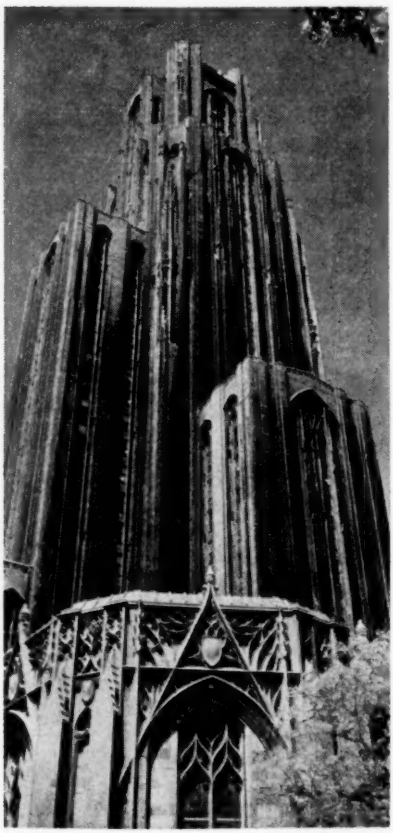


The University of Pittsburgh campus (center) and the City whose Renaissance it shares.

The Campus

The center of today's campus and of undergraduate study is the Cathedral of Learning, the tallest college building in the world. The Cathedral towers 42 stories over a more than 12-acre sweep of lawn. On one side is the Heinz Memorial Chapel, the center for campus spiritual life, and on another, the Stephen Foster Memorial and auditorium, a tribute to the Pittsburgh composer.

Nearby is a large quadrangle of student, faculty, and administrative residence halls and the Student Union, hub of student activities. The lower campus also includes George Hubbard Clapp Hall, the recently constructed home of the Division of the Natural Sciences.



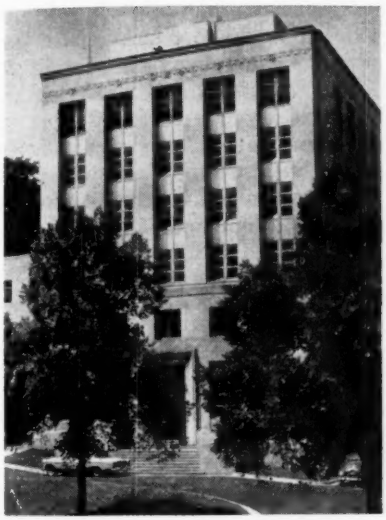
Architecturally a modern adaptation of the Gothic tower modified to the practical needs of a great university, the Cathedral of Learning suggests in height and reach the spiritual values which underlie university education.

On the upper campus, past the six buildings of the University's engineering area, is the University's Health Center, a thriving matrix of research, health education, and hospital and clinic service to the entire area. One large new building in the Health Center is devoted to the unique Graduate School of Public Health. Beyond it, at the top of a hill near Pitt Stadium, is the School of the Health Professions building, where, in an unusual and advantageous arrangement, the Schools of Medicine, Dentistry, Nursing, and Pharmacy are housed together. There, in the 13-story building, are lecture rooms, counseling area, student lounges and cafeteria, research laboratories, administrative offices, and a 140,000-volume library.

Below the Health Center but above the lower campus is the area of engineering activities. There are six buildings in Pitt's engineering area—Engineering Hall, Thaw Hall, State Hall, Mineral Industries Building, Pennsylvania Hall, and the Chemical Engineering Building.

The Schools of Engineering and Mines are among those which will be significantly benefited by the University's new development program. As a part of the first phase in the long-range program, the University recently launched a fund-raising campaign to obtain the necessary resources for an early improvement of certain facilities of the Schools and for the purchase of new equipment. The program includes the renovation of Pennsylvania Hall and other buildings.

Of the buildings in the engineering area, Engineering Hall is the newest.



This is Engineering Hall, built in 1955, the newest of six buildings housing the University of Pittsburgh's Schools of Engineering and Mines.

Completed and in use since 1955, it links Thaw Hall and Old Mellon Institute into a continuous four-hundred-foot structure, and holds office, classroom, and laboratory space for the chemical, civil, electrical, industrial, and mechanical engineering departments. Contained in Engineering Hall are a wind tunnel capable of developing speeds up to three hundred miles an hour, laboratories for the study of hydraulics, soil mechanics, strength of materials, electronics, stress analysis, materials handling, and chromatography, and a library, which was made possible by a grant from an alumnus, George M. Bevier.

One of the smaller and more intimate points of interest to members of the ASEE who will come to Pittsburgh this June is the façade of Engineering Hall. Among the official seals and insignia which decorate the façade around the top of Engineering Hall and which are symbols of the degrees offered by the University, the ASEE seal holds an honored, central position. The American Society for Engineering Education had its first permanent headquarters at Pitt, which remained its home from 1914 until 1947.

A Great Tradition

Engineering study at Pitt began more than a century ago, when the rapidly growing industrial giant that is Pittsburgh industry began to demand trained men to guide and govern it. As early as 1842 courses in engineering were offered to men interested in augmenting their "classical" studies with "scientific" subjects. By 1856 these subjects had developed into a course of study separate from and parallel to the classical field, and the Department—later the School—of Engineering was founded.

It was one of the earliest schools of engineering established in the United States and the first west of the Allegheny Mountains.

The School of Mines was established by an act of the State Legislature approved July 5, 1895. Although originally the Schools of Engineering and Mines were organized and operated separately, today the two Schools, retaining their identities, operate in a beneficially complementary manner under the same administrative dean.

Some of the great figures of engineering history also are part of the history of engineering at the University of Pittsburgh. Samuel P. Langley conducted experiments resulting in the first successful heavier-than-air craft—only a part of his contributions to science during his association with the University. Professor Reginald A. Fessenden, a close associate of Thomas Edison, came to the School of Engineering in 1893 and during his stay at the University made the basic ex-

periments which resulted in his demonstrating the transmission of sound without the use of wires.

Today the Schools of Engineering and Mines have expanded so that they offer nine basic degrees. In the School of Engineering degrees are offered in chemical, civil, electrical, industrial, and mechanical engineering (with an aeronautical option). The School of Mines offers degrees in geological, metallurgical, mining, and petroleum engineering. All nine departments give both the bachelor of science and master of science degrees, and the departments of chemical, electrical, mechanical, and metallurgical engineering offer doctor of philosophy degrees.

The wheel-like structure of a university with its hub of liberal arts offers the student definite advantages. At the University of Pittsburgh one advantage for the undergraduate engineer is the opportunity of participating in a five-year plan leading to two degrees—the bachelor of science degree from the School of the Liberal Arts at the end of the fourth year and the bachelor of science degree from a department in the Schools of Engineering and Mines at the end of the fifth year.

In the evening, extensive undergraduate degree-granting programs are offered in electrical, industrial, mechanical, and metallurgical engineering. A two-year undergraduate engineering program is also offered at the University's Johnstown College, 70 miles east of Pittsburgh, for students in that area.

One student in four of the total University undergraduate enrollment is registered in the Schools of Engineering and Mines.

A special program each year provides a graduate educational opportunity for hundreds of carefully selected graduates in engineering and sciences who are recruited from the undergraduate schools of the United States by Pittsburgh industries. This program, called Graduate Work in Industry, originated at the University of Pittsburgh, and is now followed by many engineering schools throughout the country. Courses are offered to engineers and scientists both on the Pitt campus and in the industrial centers of the participating companies.

The Schools of Engineering and Mines have been named as one of the engineering schools qualified to teach advanced nuclear engineering. Work in this field is being conducted in cooperation with the Bettis Atomic Power Division of the Westinghouse Electric Corporation.

A strong program of engineering research at Pitt is conducted by the Engineering Research Division, a charter member of the National College Research Council. Nearly a quarter of a million dollars is spent annually in this area, some of which is for basic engineering research, some for industrial projects, and some for government research.

The advantages of a university being located in an urban environment are wide and far-reaching. For student engineers the advantages are even more distinct. The cross-current of vitality that flows between engineering teachers and engineers and managers of industry, and between theory and practice is ever-present in Pittsburgh, a community which seems to strike a delicate balance of the ever-changing scale of past, present, and future.

Supplement to

AN ENGINEER'S LIBRARY

Guide to the Profession . . .

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Prepared as a supplement to the "Dean's List" published in the JOURNAL, January 1958. Reprints of the first list and of this one are available from the office of the Secretary for twenty-five cents each.

Appleyard, Rollo. *Pioneers of Electrical Communication.* London, Macmillan, 1930.

Short accounts of the lives and works of ten founders of modern electricity, including Maxwell, Volta, Ohm, Ampère, Hertz, Oersted, and Heaviside. Each essay describes the scientific experiments for which these men were noted.

Brown, Harrison, James Bonner, and John Weir. *The Next Hundred Years; a Discussion Prepared for Leaders of American Industry.* New York, Viking Press, 1957.

Summarizes symposia held on resources and population problems for industry. It attempts to forecast the future of our scientific-technological-industrial civilization and, in doing so, discusses the interrelationship between man and his resources.

Burlingame, Roger. *Backgrounds of Power; the Human Story of Mass Production.* New York, Scribner, 1949.

Develops the history of the machine and the production line in American industry from its beginnings.

——. *Machines That Built America.* New York, Harcourt, 1953.

Informal history of the great events in machine production and brief sights of the great figures in this history.

Chalmers, Thomas W. *Historic Researches.* New York, Scribner, 1952.

Outstanding physical and chemical discoveries, interestingly depicted in historical perspective. "No engineer can now say with any assurance what aspects, if any, of physical or chemical research lie outside his sphere. Never before has it been truer than now that the physics of to-day is the engineering of to-morrow."

Chapman, Seville. *How to Study Physics.* Rev. ed. Cambridge, Mass., Addison-Wesley Press, 1949.

Do you really know how to study effectively? This book may surprise you with its wealth of practical ideas on making notes, solving problems, performing experiments, taking examinations, etc. Grasp of fundamental principles is advised, rather than rote memorization. Introductory chapters pose the questions, "Why go to college? Why study physics?"

Clarke, Arthur C. *Interplanetary Flight.* New York, Harper, 1952.

A survey of the possibilities and problems of interplanetary flight by the Assistant Secretary of the British Interplanetary Society. Mathematics has been relegated to an appendix, leaving a readable account of the science of "astronautics" that still avoids being merely a series of generalities. Although not concerned primarily with rocket technology, the engineering problems of space flight are not disregarded.

Compton, Arthur H. *Atomic Quest.* New York, Oxford University Press, 1956.

How theoretical small-particle physics merged with practical large-scale engineering to produce the A-bomb. A participant in the "atomic quest" narrates the fantastic tale, with emphasis on men and motives. "Vision," "Faith," "Work," "Choice," and "Hope" are the chapter headings, which lead from initial awareness of atomic energy to its prospects for mankind.

Copley, Frank Barkley. *Frederick W. Taylor, Father of Scientific Management.* New York, Harper, 1923.

A two-volume biography of the enneer who was responsible for many of the classic contributions to the fields of industrial engineering and management. Gives a detailed account of Taylor's career and introduces the reader to many of the important engineers of that period who came in contact with Taylor.

De Forest, Lee. *Father of Radio: the Autobiography of Lee de Forest.* Chicago, Wilcox & Follett, 1950.

De Forest's own story of the development of the three-electrode vacuum tube, feedback circuits, amplifiers, and other common circuits of modern radio. He sketchily documents his years-long court battle with Armstrong over the patents for the feedback circuits.

Duke, Neville, and Edward Lanchbery. *'Sound Barrier'; the Story of High-Speed Flight.* 8th ed. London, Cassell, 1955.

Presents the obstacles to supersonic flight already faced and overcome in the last decade, and the problems that lie ahead. The "sound barrier" as a problem of flight research is being rapidly replaced by the "heat barrier." The book provides an insight into the manner in which the team of designer, aerodynamicist, engineer, physicist, and pilot plan the campaign for another conquest of the sky.

Dyer, Frank L., and Thomas C. Martin. *Edison, His Life and Inventions.* 2 vols. New York, Harper, 1919.

A readable biography of the prolific inventor, written before his death and thus benefited by contact with the man himself. Many chapters with interesting contemporary statements concerning the motion picture invention are carried over intact from an earlier edition. The second volume contains sketches and descriptions of Edison's most important inventions and a list of his patents.

Einstein, Albert, and Leopold Infeld. *The Evolution of Physics.* New York, Simon and Schuster, 1942.

Reveals how scientific and philosophical theories may rise and fall in the "eternal struggle of the inventive human mind for a fuller understanding of the laws governing physical phenomena." Popular but authoritative treatment in chatty style, employing simplified analogies for greater clarity of presentation.

Fraser, Charles G. *Half-Hours with Great Scientists.* New York, Reinhold, 1948.

Sub-titled "The Story of Physics," this well-illustrated book shows men of science at work from earliest to recent times. Their aims, methods, and accomplishments are described in successive "stories" of mechanics, acoustics, optics, thermics, and electricity and magnetism. Source quotations give added flavor to this interesting record of scientific progress.

Giedion, Sigfried. *Mechanization Takes Command; A Contribution to Anonymous History.* New York, Oxford University Press, 1948.

The evolution of mechanization in the last century and a half, its effects on modern civilization, and its historical and philosophical implications.

Hart, Val. *The Story of American Roads.* New York, William Sloane, 1950.

An account of the high spots about roads and road building in North America, from the first white man's use of Indian trails to the newest superhighway.

Heathcote, Niels H. de V. *Nobel Prize Winners in Physics, 1901–1950.* New York, Schuman, 1953.

Here we may meet the Nobel laureates and listen as they acquaint presentation-ceremony audiences with their work. Brief biographies are followed by descriptive summaries, extracts from Nobel lectures, and evaluative comments. Achievements are viewed not in isolation, but as focal points in physics history.

Hildebrand, Joel Henry. *Science in the Making.* New York, Columbia University Press, 1957.

A highly-interesting group of essays on what science is and how it develops. The author draws upon his own discoveries in the theory of solutions to illustrate his points.

Hill, Forest G. *Roads, Rails and Waterways; the Army Engineers and Early Transportation.* Norman, University of Oklahoma Press, 1957.

History of the part played by Army engineers in the opening of the West, from 1812 to the Civil War.

Hunsaker, Jerome C. *Aeronautics at the Mid-Century.* New Haven, Yale University Press, 1952.

Taken from the author's Terry Lectures at Yale University, this consideration of the impact of the air-

plane upon civilization is divided into three parts: aircraft development through research; the present state of the art of aeronautics; and the effects of civil and military aeronautics on society.

Kirby, Richard Shelton, Sidney Withington, Arthur Burr Darling, and Frederick Gridley Kilgour. *Engineering in History*, New York, McGraw-Hill, 1956.

Traces the development of engineering in Western civilization from its origins into the twentieth century and relates this development to other human activities.

Lessing, Lawrence. *Man of High Fidelity: Edward Howard Armstrong*. Philadelphia, J. B. Lippincott, 1956.

A full biography of the inventor of the feedback circuit, superheterodyne circuits, and FM radio. The feedback circuit invention was hotly contested by de Forest and has been legally attributed to the latter inventor.

Mach, Ernst. *The Science of Mechanics*. La Salle, Illinois, Open Court Publishing Co., 1942.

A translation from the German of Dr. Mach's critical and historical account of the development of the science of mechanics.

MacLaren, Malcolm. *The Rise of the Electrical Industry During the Nineteenth Century*. Princeton, Princeton University Press, 1943.

An excellent survey of the key developments in all phases of the electrical industry during the nineteenth century. The discussion of hundreds of innovations, some large, some minute, provides a compact picture of the ways in which electricity is utilized.

McNicol, Donald. *Radio's Conquest of Space; the Experimental Rise in Radio Communication*. New York, Murray Hill Books, 1946.

An account of the enginering developments in radio communications written for the serious layman. The author, past president of the Institute of Radio Engineers, uses no mathematics but incorporates simple wiring diagrams to explain the use of various phenomena utilized by radio engineers.

Milbank, Jeremiah. *The First Century of Flight in America*. Princeton, Princeton University Press, 1943.

A history of aeronautics in the United States before 1900, recording the aeronautical events and personalities of the pre-airplane age. Newspapers, letters, pamphlets, treatises, memoirs, and material from the United States Patent Office have been the main sources for the author's research. Of especial interest are the accounts of early balloon flights in America.

Norrie, Charles M. *Bridging the Years; a Short History of British Civil Engineering*. London, Edward Arnold, 1956.

A brief account of the British Civil engineering profession from its beginnings through World War II, written "mainly for young civil engineers who want to know something about the historical background of the occupation they have decided to follow."

O'Neill, John J. *Prodigal Genius; the Life of Nikola Tesla*. New York, Washburn, 1944.

A popular, but full, narrative of Tesla's work. Factually describes his eccentricities as well as his genius in the development of polyphase alternating current machinery and systems.

Parke, Nathan G. *Guide to the Literature of Mathematics and Physics; Including Related Works on Engineering Science.* 2nd edition. New York, Dover Publications, 1958.

Engineers and scientists must be familiar with the literature of their own and related fields. This guide presents helpful suggestions on using technical library materials efficiently, as well as advice on reading and study habits. An extensive bibliography to 1956 is appended, arranged alphabetically by topics of mathematics, physics, and engineering. The guides by Parke and Whitford may well be used together in supplementary fashion.

Pollack, Philip. *Your Career in Physics.* New York, Dutton, 1955.

What it takes to become a physicist, and the nature of his work. For those who qualify, opportunities abound in many areas, such as atomic energy, electronics, optics, meteorology, etc. "Prospective physicists should realize that there is no sharp line of demarcation separating pure research in physics from applied research and engineering."

Rhodes, Frederick Leland. *Beginnings of Telephony.* New York, Harper, 1929.

An excellent history of the telephone, telephone apparatus, and telephone systems and their technical development. Includes an account of the patent litigation described as one of the most important and most protracted legal controversies over mechanical or electrical contrivances under the U. S. patent system.

Singer, Charles. *A History of Technology.* Oxford, Clarendon Press, 1954–1958.

A monumental five-volume work tracing the development of the technologies from pre-historic times to the beginning of the twentieth century.

Skilling, Hugh H. *Exploring Electricity; Man's Unfinished Quest.* New York, Ronald Press, 1948.

A versatile and noted teacher of electrical engineering here turns to a short history of electricity in physics and electrical engineering. He describes the fundamental phenomena of electricity and the means by which they were discovered and proved.

Smith, Alpheus W. *Careers in Physics.* Columbus, Ohio, Long's College Book Co., 1951.

Parallels Pollack on choosing a physics career from many types. "Engineers recognize that physics is the basis of engineering sciences, and physicists should be equally aware that engineering sciences are the fruiting of much that has been done in chemistry and physics, and that physics cannot replace engineering any more than engineering can replace physics and chemistry."

Struik, Dirk J. *Yankee Science in the Making.* Boston, Little, Brown, 1948.

A history of growth of the natural, physical, and engineering sciences in New England, from the time of the Pilgrim Fathers to the beginning of the Civil War.

Taylor, Frank Sherwood. *A History of Industrial Chemistry.* New York, Abelard-Schuman, 1957.

A well-written short history of industrial chemistry from the earliest times to the present. Has numerous photographs.

Taylor, Frederick W. *Scientific Management:* comprising *Shop Management, The Principles of Scientific Management,* and *Testimony before the Special House Committee.* New York, Harper, 1947.

A statement of the theory and principle of "scientific management" as set forth in several of Taylor's important works.

Veblen, Thorstein. *Engineers and the Price System.* New York, Viking Press, 1921.

A thoughtful and controversial interpretation of the engineer's role in society, by an eminent American economist.

Walker, Ernest E. *Aviation, or Human Flight through the Ages.* Washington, Aeronautics Education Foundation, 1939.

Beginning with the flying aspirations of the ancients, the author presents the essentials of flying history in a logically connected narrative in relationship to human affairs. His account gives not only some knowledge of achievements, but also something of the spirit which inspires flying. The final chapter, "Epoch-Making Flights," is devoted to the exploits of several contemporary heroes of modern aviation.

Watson-Watt, Robert. *Three Steps to Victory; a Personal Account by Radar's Greatest Pioneer.* London, Odhams Press, 1957.

A personal and detailed account of the development of radar from the beginnings of modern radio to the early 1950's. Includes accounts of the use of radar in various phases of World War II in the European theater.

Whitford, Robert H. *Physics Literature.* New York, Scarecrow Press, 1954.

"This is a survey of physics literature at the college level. It describes the many types and forms available, selects a representative working collection, and outlines efficient library methods. Arrangement is by most usual lines of inquiry, termed 'approaches,' e.g., the 'historical approach,' when items pertaining to history are sought. Background materials have been interspersed for greater interest and information." See also Parke's guide.

Wilson, Mitchell. *American Science and Invention.* New York, Simon and Schuster, 1954.

A pictorial history of American science and invention from the time of the early settlers to electronics and chain reactions.

Wilson, Neill C., and Frank J. Taylor. *The Earth Changers.* Garden City, N. Y., Doubleday, 1957.

This is the story of the Hoover Dam, which opened a new era of heavy construction on all continents.

Wright, Wilbur. *The Papers of Wilbur and Orville Wright.* Marvin W. McFarland, editor. 2 vols. New York, McGraw-Hill, 1953.

The Wright brothers often expressed the desire to present a full, unvarnished account of their work, especially of their original scientific investigations as distinct from their merely technical accomplishments. These two volumes, which include all papers relevant to the evolution of the airplane and the principles of flight discovered by the Wrights, fulfill this wish. Of particular interest are the several hundred letters between the Wrights and Octave Chanute, 1900–1910.

Yost, Edna. *Frank and Lillian Gilbreth, Partners for Life.* New Brunswick, N. J., Rutgers University Press, 1949.

An interesting account of the successful careers of a husband-and-wife team who made important contributions in the fields of motion study, micromotion, and fatigue study.

OPINIONS ON ENGINEERING EDUCATION

WARREN E. WILSON

Chairman of Engineering, Harvey Mudd College, Claremont, California

The classical guide for engineering education today is the "Report on Evaluation of Engineering Education" prepared by a committee of ASEE during the years 1952–55. In the summary of this report, the following statement is made:

> Engineering Education must contribute to the development of men who can face new and difficult engineering situations with imagination and competence. Meeting such situations invariably involves both professional and social responsibilities. The committee considers that scientifically oriented engineering curricula are essential to achieve these ends.

This Report states in considerable detail the objectives of engineering education and the means of implementing a program designed to attain these objectives. Great emphasis is placed on the selection of an inspirational faculty and the design of curricula which eliminates traditional emphasis upon engineering specialties and handbook methods.

In 1956, after engineering educators had had a full year to digest the Report, the writer made a study by means of a questionnaire directed to members of ASEE. The objective of this study was to determine the reaction of engineering educators and others who might be interested in engineering education to certain radical proposals which might conceivably be considered to follow from the recommendations of the Evaluation Report. The questionnaires were sent to approximately one tenth of the membership of the Society. Sixty-nine per cent returned completed questionnaires. The first question was: "What would be your reaction to a uniform four year engineering curriculum to replace all present four year curricula in civil engineering, mechanical engineering, electrical engineering, aeronautical engineering and closely allied curricula consisting essentially of the following courses, and resulting in a Bachelor of Science in Engineering at the end of four years:

English	12 Credits
Humanities	12 Credits
Mathematics	26 Credits
Physics	20 Credits
Chemistry	12 Credits
Drawing	4 Credits
Mechanics	12 Credits
Elec. Theory	12 Credits
Thermo. & Fluid Mechanics	8 Credits
Engrg. Analysis & Design	18 Credits
R.O.T.C.	6 Credits
Physical Education	4 Credits
Total	146 Credits

The response to this question was most interesting. Of the academic members of the Society:

9% favored this proposal strongly.
32% favored it mildly.
4% were neutral.
22% objected to it mildly.
32% objected to it strongly.

Among the members of the Society who were not associated with academic institutions, the response was as follows:

20% favored it strongly.
40% favored it mildly.
2% were neutral.
22% opposed it mildly.
11% objected strongly.

This is a rather startling endorsement of a most radical proposal. While only 41 per cent of the academic members favor it, there was little expecta-

tion before this questionnaire was distributed that such a proposal would meet with much favor at all. About two-thirds of the non-academic members of the Society were definitely in favor of this scientifically oriented curriculum. This was certainly a definite endorsement of the concept. The following question was posed later in the questionnaire: "Do you think a uniform four year curriculum would be met with favor by industrial employers?" The academic members of the Society answered as follows:

Yes, by most employers, 13%
Yes, primarily by large companies, 27%
Approximately one-half yes, one-half no, 26%
No, by most employers, 27%
No, by practically all employers, 4%

The non-academic members of the Society replied as follows:

Yes, by most employers, 24%
Yes, primarily by large companies, 30%
Approximately one-half yes, one-half no, 24%
No, by most employers, 18%
No, by practically all employers, zero

The future of specialized curricula was examined by the question, "What do you believe will happen to specialized curricula such as sanitary engineering during the next ten years?" The members of the Society replied as follows:

	Academic	Non-Academic
Will be entirely eliminated	3%	1%
Will be eliminated from most colleges	7%	11%
Will be decreasing in number	40%	38%
Will be about as numerous as now	40%	26%
Will be more numerous than now	7%	13%

We see in the answers to these questions evidence of a feeling that something rather radical should be done in engineering education, but not a belief that it will be done. Academic people and non-academic alike seem to feel that a scientifically oriented engineering curriculum would be desirable and that industry would accept it, but at the same time they expect that the highly specialized curricula would at best decrease slowly in numbers and be with us for many years to come.

The development on many campuses of curricula called "Engineering Science," "Science Engineering" and others which resemble closely the one described in the questionnaire is most interesting. This is particularly so in the light of the rejection in 1953 of the Evaluation Committee's proposal for bifurcation. The questionnaire revealed extensive sentiment favoring the "Professional-Scientific" curriculum, and today we have many such courses of study. In other words, we have bifurcation, whether we want it or not.

EDUCATIONAL REACTORS

Iowa State College has announced a contract with the Atomic Energy Division of American-Standard for a 10 kw training reactor of the Argonaut type. The University of Tennessee has applied for a license to construct a research reactor. Tulane University is acquiring a subcritical nuclear reactor and associated laboratory from the Curtiss-Wright Corporation.

THE PROBLEM OF THE UNDER-ACHIEVING STUDENT

MIRIAM FARIES

Associate Professor and Psychologist
Department of Student Life

JAMES D. PERRY

Statistician
The City College of New York

College admissions officers are continually searching for more discriminating instruments to use in selecting students. Though many different measures have been tried, the high school average has consistently been proven to be the best single measure of capacity to do college work. Entrance tests combined with high school average generally yield even better predictive evaluation.

In this connection, the student whose high school record is mediocre, but who does well on entrance tests, presents a problem. Such a student is frequently labeled an "under-achiever," since his potential as indicated by high test results is often not shown in comparable grades. Such a student creates difficulty both for the counselor and for himself: for the counselor because the problem often cannot be remedied in short-term counseling and for the student because his failure in performance may be rooted in deep-seated unconscious mechanisms which he does not understand and hence cannot surmount.

Tentative beginnings on studying this problem go back many years. As early as 1927 Shuttleworth found failing students responding positively to statements which indicated dependency needs and lack of initiative (1). Terman in a follow-up of his study of gifted children found that "intellect and achievement are far from perfectly correlated" (2). In a study by Burgess, under-achievers were found to be higher in dependency needs than normals, to have strong desires for freedom from restraint, and to be less adaptive intellectually (3). Among those whose academic performance is lower than test performance, Kirk found students exhibiting a symptomology characterized by being "basically resistant on an unconscious level to any externally imposed task"—an attitude concealed by "hardworkingness and earnest dutifulness" (4). Many other studies reveal similar findings, several of which point to the fact that discrepancy between ability and achievement is frequently a sign of personality maladjustment, beginning in childhood (5, 6, 7, 8, 9).

At City College the under-achieving student is easily identified, since the high school record and entrance test results are a basic part of each student's record available to the counselor even before the first conference. The majority of students are admitted on their high school average, though a battery of entrance tests are part of the required admission procedure. Students who fail to earn the requisite high school average * may also take entrance tests, and if the results are sufficiently high to compensate for a lower high school average, they too may be admitted on this latter basis.

Brunstetter, studying the class which entered the college in 1951, found that

* The requisite average at the time of this study was 80.

the number of withdrawals among those admitted by composite score (by our definition, under-achievers) was four times that of those admitted by high school average (by our definition, normals) (10).

Description of Procedure

Many students voluntarily seek a conference with a counselor to gain an evaluation of their record in terms of their chances of success in college. When the high school average is markedly lower than the entrance test scores, often the student states that for varying reasons he did not apply himself in high school, but he has no doubt of his ability to do acceptable college work. In order to test the hypothesis that under-achievement is a sign of maladjustment or personality defect not under the conscious control of the student, a follow-up study of such students was made to determine whether they were able to perform in line with their potential as shown by entrance tests, or whether they continued to work at a level well below their potential, as they did in high school.

The entire freshman class entering the School of Technology (day session) in September 1953 was used as the basis for the study, and the normal or control group was composed of those admitted on high school average. The under-achieving or experimental group was comprised of those whose high school average would have debarred them had they not compensated for this deficiency by high test results. Success was defined as completing the junior year in the normal amount of time, while failure was designated as being dropped for poor scholarship, voluntary withdrawal or changing degree objective.

Results

Of a total of 637, four hundred fifty-five were admitted by high school average alone and approximately 55 per cent of these were successful. Of those admitted by composite score, numbering 182, approximately 18 per cent were successful. Submitting the figures to Chi square analysis, the result is $\chi^2 = 24.9$ which is significant beyond the .01 level.

Statistical Analysis

	Reached Junior Year or Above in Engineering	Did Not Reach Junior Year	Total
Entered by H.S. Average (H.S. Ave. 80 or above)	161	294	455
Entered by Composite Score (H.S. Ave. below 80)	28	154	182
Total	189	448	637

A trend was also observed which seemed to indicate that the greater the discrepancy between ability and achievement, the greater the possibility of failure in college. The numbers, however, were too small to warrant statistical treatment.

Conclusions and Implications

Through counseling with under achievers over a period of years, the findings of the research studies previously quoted have been corroborated. The basis of under-achievement appears to be resistance, either direct or

indirect. When the resistance is direct, the student is openly rebellious, resenting set assignments and curricular requirements and often neglecting home study and class attendance. He will frequently do voluntary reading in advanced texts while complaining of the routine character of basic required work. When the resistance is indirect, the student is outwardly conforming and may spend many hours trying to study, but he complains of inability to concentrate or lack of time to complete assigned work. He seems to lack the confidence which is necessary to take initiative in attacking academic work and he frequently complains that his professors do not offer sufficient explanation of assignments. It seems possible that hostility is the basis of the difficulty. In the first case, the hostility is overt, while in the second the hostility is repressed and manifests itself in indirect ways.

There would appear to be two implications which might be drawn from this study: 1. In terms of admission procedures, the under-achieving group warrants further study. 2. Counselors should be alerted to the problems of the under-achiever. It would be interesting to ascertatin whether a concerted effort in offering counseling help to this group would enable a greater percentage to function at their potential level and to succeed in college work. This has already been done with individual students, but the group as a whole has not been approached.

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10. Brunstetter, Philip H., *A study of student withdrawals at the City College of New York*. Uptown Center, Day Session, 1951. Unpublished Type B Project. Teachers College, Columbia University, 1956.

AT THE ANNUAL MEETING IN PITTSBURGH

In Schenley Park, a short walking distance from the Student Union, which will be the ASEE registration headquarters, is the Phipps Conservatory. This is the largest area under glass in the world and the various conservatory rooms always contain interesting exhibits. There is a cactus room, a tropical room, and an orchid room, among others. The annual fall and spring flower shows held here have won national recognition. The Conservatory is open daily without charge from 9:00 a.m. to 5:00 p.m.

GUIDANCE–THE ENGINEER'S RESPONSIBILITY

L. G. SMITH

Chairman, Committee on Guidance
Engineers' Council for
Professional Development,
New York

Engineers generally are aware of the importance that engineers play in our economy and of the increasing role that they will fill in the future. In spite of fluctuations in the business cycle, the continuation of our technological progress will require a steady and increasing flow of highly qualified engineering graduates into the profession. Our economy and our national defense need engineers and will continue to need them over the years in increasing numbers. We, as engineers, have an obligation to our profession and a continuing responsibility to interest qualified young people in our secondary schools in entering the engineering profession.

The Guidance Committee of the Engineers' Council for Professional Development has been engaged in guidance work to interest those secondary school students possessing the necessary aptitudes to embark on engineering careers. Under the sponsorship of the national committee, the country has been divided into eight regions, each with a regional chairman. The regional chairmen have organized state committees to implement the guidance work at the "grass roots" level. It is here that the effective guidance work is accomplished. To date, committees in 48 states and the District of Columbia have been organized. These state guidance committees work directly with the high schools, counseling students to study mathematics and the sciences and urging those who show the necessary aptitudes to consider a career in engineering.

The state guidance committees carry out their objectives through a wide variety of projects and programs, through talks and panel presentations before student groups and assemblies, and before teachers, vocational counselors and parents; through inspection trips and the showing of appropriate technical films; through the promotion of engineering clubs and science fairs; through individual counseling; and through myriad other activities. This is effort by engineers for their profession. This is a professional activity which is not intended to favor particular industries or technical specialties. Rather, the effort is directed toward strengthening the engineering profession so that it may be equal to the task of keeping our technical progress moving forward.

Because not all high school students have the necessary aptitudes, and since it is necessary to interest the qualified to enter engineering colleges, help is needed at the local level to carry on adequately these guidance activities. There is a place and a need for all engineers who are interested to engage in this work. This is written as an appeal to the members of ASEE to volunteer in assisting the efforts of your State Guidance Committee. If there is no committee in your state, the chairman of your region will be glad to hear from you. Following is a list of regional and state chairmen with whom you can communicate:

ENGINEERS COUNCIL FOR PROFESSIONAL DEVELOPMENT GUIDANCE COMMITTEE

Regional Chairmen
1958–59

Region I
Donovan, Dean E.
University of New Hampshire
Durham, New Hampshire

Region II
Roemmele, Herbert F.
Placement Officer
Cooper Union
Cooper Square
New York 3, New York

Region III
Jeffers, F. J.
Baltimore Gas & Electric Co.
Power Production Stas.—Westport
Baltimore 3, Md.

Region IV
Lampe, J. H.
Dean of Engineering
North Carolina State College
Raleigh, North Carolina

Region V
O'Connell, G. P.
Educational Relations Section
General Motors Corporation
3044 West Grand Boulevard
Detroit 2, Michigan

Region VI
Drought, Dean A. B.
Engineering Dept.
Marquette University
1515 W. Wisconsin Ave.
Milwaukee 3, Wisconsin

Region VII
Matteson, Robert
California Research Corporation
200 Bush Street
San Francisco, California

Region VIII
McGuire, Prof. J. G.
Assistant to Dean of Engineering
Texas Agriculture and Mechanical College
College Station, Texas

Canada

Young, D. A.
840 Riverwood Avenue
Fort Garry, Manitoba

SUMMER SEMINARS AT PENN STATE

A diversified program of seminars for engineers and scientists will be conducted this summer by The Pennsylvania State University.

June 1 to 26. Seminar on Reactors and Radioisotopes.
June 7 to 12. Electrical Contacts Seminar.
June 7 to 12. Machinability Seminar.
June 7 to 19. Underwater Missile Engineering Seminar.
June 14 to 19. Electrical Precipitation Seminar.
June 28 to July 3. Plastics Seminar.
July 5 to 10. R & D Management Development Seminar.
September 14 to 25. Report Writing Seminar.

Inquiries concerning these programs should be directed to Engineering Seminars, Extension Conference Center, The Pennsylvania State University, University Park, Pa.

REPORT ON "PHYSICS IN ENGINEERING EDUCATION 1958"

R. J. SEEGER

Deputy Assistant Director
National Science Foundation
Washington, D. C.

E. WEBER

President
Polytechnic Institute of Brooklyn

As a paper of interest to both engineers and physicists, this article is being published also in the April issue of *Physics Today*.

About three years ago a "Progress Report on Physics in Engineering Education" (1) ended with the hope that "through pioneering and experimental, cooperative planning physicists and engineers will now enter enthusiastically and adventurously a new era in the teaching of Physics and in the teaching of Engineering." This hope was the result of a report (2) of the Committee on Evaluation of Engineering Education by ASEE in June 1955. At its June 1958 meeting, E. Weber, Chairman of the Follow-up Committee (*ad hoc*) on Evaluation of Engineering Education, made a more detailed report of the engineering sciences, which had been merely mentioned in the original report. It consisted of a number of individual reports of special committees, varying from the presentation of broad principles to detailed courses. The subjects were:

Mechanics of Solids
Mechanics of Fluids
Transfer and Rate Processes
Thermodynamics
Electrical Sciences
Nature and Properties of Materials
Engineering Analysis and Design

A Committee of the American Institute of Physics had also issued a report on "The Role of Physics in Engineering Education." The very first recommendation of this Committee was the need for "improved communication between Engineers and Physicists at the institutional level to discuss objectives and determine mutual needs." It occurred to the writers that a check on communication between physics departments and engineering departments might be in order in view of the lapse of three years. Accordingly, with the approval of E. Hutchisson, Chairman of the original AIP Committee, the writers agreed upon a questionnaire that would be sent simultaneously to the engineering schools by the ASEE and to the physics departments of the same schools by the AIP. The questions in general were similar. The physics questionnaire asked:

1. To what extent have there been discussions between Physics and Engineering Departments concerning the appropriate divisions between courses in physics and those in engineering sciences?

2. Have such discussions and others assisted in determining the courses, or the contents of courses, in Physics Departments? In Engineering Departments?

3. To what extent, if any, have endeavors to formulate the subjects of

engineering sciences reacted upon the physics teaching as far as you can judge?

4. What undergraduate physics courses are now required of engineering students? Are any of the advanced physics courses popularly elected by students? Are any of the advanced physics courses elected by engineering students? In other words, what attempt, if any, has been made to utilize additional undergraduate courses in physics to supplement engineering sciences?

5. To what extent, if any, is there a definite attempt to build engineering science courses upon prerequisite physics courses?

6. It has been suggested that the Institute reactivate a committee on the "Role of Physics in Engineering Education." Is this, in your judgment, an appropriate time to restudy this matter?

A rough analysis of the physics replies was made by R. J. Seeger. A reply that seemed to indicate reasonable progress was rated as good. Evidence of greater progress was noted as very good, whereas a definite inadequacy was poor (Table 1).

The corresponding engineering questions are listed below:

1. Have there been discussions between Physics and Engineering Departments concerning the appropriate division between Physics and Engineering Sciences?

2. Have such discussions or any others assisted in fromulating curricula in Engineering Departments?

3. Have endeavors to formulate the subjects of engineering science reacted upon the physics teaching as far as you can judge?

4. What attempt, if any, has been made to utilize advanced undergraduate physics courses to supplement engineering sciences?

5. Which courses offered in the Physics Departments are required by Engineering Departments, listing both general physics and advanced undergraduate physics courses?

6. Which physics courses are most popular as electives with engineering students?

It will be noted that the first three are very similar to those in physics, the last one is quite different. Questions four and five together are believed to be comparable to physics question four. An analysis was made of these replies on the same basis as those in physics (Table 2, Evaluation A).

TABLE 1

PHYSICS REPLIES

Question No.	Total Replies	Progress		
		Poor	Good	Very Good
1	133	50	45	38
2	131	52	58	21
3	124	78	42	4
4	132	82	44	6
5	120	75	41	4
6	112	28	28	56

TABLE 2

ENGINEERING REPLIES

Evaluation A

Question No.	Total Replies	Programs		
		Negative	Perfunctory	Positive
1	110	29	75	6
2	104	36	65	3
3	104	68	34	2
4	103	96	7	0
6	109	63	44	2
Evaluation B				
1	111	9	25	77
2	111	25	15	71
3	111	43	27	41
4	111	22	39	50

Eighty-seven of the institutions sent replies from both physics and engineering departments. In general, the rating by the physicists agreed with that by the engineers, neither poor nor very good—barely good.

The engineering replies were analyzed in a somewhat different manner by E. Weber. Definitely positive or negative answers were compared with the common, perfunctory statements, which were not particularly revealing. In the answers to question six, E. Webber found that nuclear physics courses were mostly preferred; in second place, modern physics; then, atomic physics, and finally solid-state physics (Table 2, Evaluation B).

In summary:

(1) There seems to be definite evidence that some progress has been made despite the brevity of the questions and of the replies. Many of the remarks made in the answers, however, signified somewhat peculiar points of view. They do not represent the average opinion; on the other hand, they do indicate some sore spots that need attention.

(2) The second outstanding characteristic of the replies is the need for considerably more communication between engineering departments and physics departments, particularly at the local level.

(3) The writers recommend the ASEE and the AIP review the situation more thoroughly and advise upon definite steps that should be taken in order to encourage the physics and engineering faculty to solve their mutual problem by recognizing the complementary advantages of physics and of engineering teaching. It is agreed that physics should be taught as physics and engineering as engineering. Their mutual interdependence should be recognized not only as research and development out of school but in the curricula in school. Brother Conrad Gabriel of Manhattan College called our attention to a remark of Robert A. Millikan (4), "I should like to do a little bit if I can toward bridging the chasm which we have foolishly—I almost said idiotically—allowed to grow up between the physicist and the applied physicist, who is commonly called an Engineer."

The AIP Report concluded: "Recent meetings of the American Association of Physics Teachers and of the Physics Division of the American Society for Engineering Education have had sessions devoted entirely to the teaching of general physics to engineers. We urge that meetings of this kind be continued, and that whenever possible further joint meetings be held. Such meetings, by bringing together researchers and teachers, physicists and engineers, to share their experiences, their faiths, and their hopes do much to stimulate further interest and understanding of the 'Role of Physics in Engineering Education.'" If the questionnaires and their replies have any merit, it is to emphasize the wisdom of this statement—P.S.—Post Sputnik.

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EMPATHY IN ENGINEERING STUDENTS

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In the folklore of university campuses one encounters many stereotyped statements. One such statement concerning engineering students is that they are so dedicated to technical, scientific, and material development that they lose their ability—if they ever had such aptitude—to think and feel with primary emphasis upon cultural and social considerations. The stereotype of an engineering student emphasizes preoccupation with machine-like qualities as contrasted with the humanistic outlook of students who major in religion, economics, sociology, psychology, and other social sciences.

In psychological language, this stereotyped impression would be stated in terms suggesting that the typical engineering student has little empathy with people primarily concerned with social problems and values. If this is true, it would seem reasonable to speculate that engineering students might be unable to simulate the interests of people with strong social service preferences even though they deliberately set out to do so.

The author has reported data (1) which demonstrate that it is possible to fake or throw scores on an empirically constructed interest inventory. The subjects of the study were engineering students. That they were able to shift viewpoints to the extent of expressing interest patterns characteristic of men in unrelated vocational areas seems to have important bearing upon the question of engineering students' ability to empathize. For this reason, it appears worthwhile to review the findings of the study with this focus in mind.

Empathy, as used in this study, is the ability to be aware of the feelings, attitudes, and interests of others without necessarily sharing them. In more informal language, it is the process of "putting oneself in the other fellow's shoes." Empathy is considered by many as essential to understanding and communication. It is generally agreed that empathy is the result of sensitive and acute perception which develops through maturation and learning.

In the present study, scores from the *Strong Vocational Interest Blank for Men* (3) were used to determine the degree to which potential engineers could temporarily discard their own interests and identify the interests of dissimilar occupational groups, *viz.*, those described as social occupations.

Hahn and MacLean (2) have compiled a composite table of Classifications of Human Aptitudes and Abilities. Although it is recognized that people do not possess clear-cut aptitudes that are easily identifiable and subject to exact measurement, the aptitudes and abilities considered important for engineers are "numerical, spatial, scientific, mechanical, academic." Social aptitude is not listed as important for engineers. It is described as follows: "Social—ability to work with people without friction; leadership; social—sociability, cooperativeness, tact, personal pleasingness, helpfulness." The occupations for which social aptitude or ability is considered important are: "politician, teacher, personnel or social welfare worker, salesman, etc."

Procedures

Sixty-one senior engineering students (24 civil, 37 mechanical) at the Pennsylvania State University completed the *Strong Vocational Interest Blank for Men* (3) in the usual manner. Three weeks later the same examiner described to the same students the work performed by men classified by Strong (3) as Group V (social) and requested the students to "attempt to answer the questions on the inventory as you think representative men in occupational Group V would answer them." The descriptions of the work performed by men in occupational Group V were obtained from the *Dictionary of Occupational Titles* (4).

The interest tests were scored for the thirty-five individual occupational scales and the six group scales for the first and second administrations of the test. Clusters of interests in occupational Groups II and V were of central concern to the present discussion. Occupational Group II includes: mathematicians, engineers, and chemists. Occupations included in Group V are: Y.M.C.A. secretary, personnel manager, Y.M.C.A. physical director, social science teacher, city school superintendent, and minister.

Results

A series of interest scores was obtained showing how closely the responses given by the examinees correspond to those typically given by men employed in occupational Groups II and V. A scale of letter grades is also provided, in which A represents very close resemblance to the particular occupational group, B +, B, and B − lesser degrees of resemblance, and C + or C interest patterns quite different from those of the particular occupational group.

Because of the unusual dispersion of standard scores, the distribution of scores is reproduced in Table I along with data showing the changes in standard scores from first to second tests for occupational Groups II and V.

TABLE I

DISTRIBUTION AND MEANS OF STANDARD SCORES OF ENGINEERING STUDENTS WHEN SCORED FOR TWO OCCUPATIONAL GROUPS, FIRST AND SECOND TESTS

Occupational Group II				Occupational Group V			
1st Test		2nd Test		1st Test		2nd Test	
Score	f		f	Score	f	Score	f
59–61	2			59–61	0	68–70	2
56–58	6			56–58	1	65–67	10
53–55	2			53–55	1	62–64	8
50–52	5			50–52	1	59–61	18
47–49	6			47–49	0	56–58	8
44–46	8			44–46	6	53–55	11
41–43	5			41–43	7	50–52	1
38–40	8			38–40	4	47–49	2
35–37	4			35–37	6	44–46	1
32–34	3		1	32–34	13		
29–31	1			29–31	12		
26–28	5			26–28	5		
23–25	3			23–25	3		
20–22	3		60	20–22	2		
m = 41.54		m = 20.97		m = 34.98		m = 59.57	
SD = 10.71		*SD = 0		SD = 7.62		SD = 5.18	
σm = 1.38		*σm = 0		σm = .98		m = .67	
*r = 0				r = −.070			
σD = 1.38				σD = 1.15			
t = 14.88				t = 21.38			

* Because of the unusual dispersion of scores it was safe to assume an SD, σm, and r of zero.

A comparison of the percentages of student engineering subjects in this study who earned the respective letter grade ratings with the findings Strong (3) reports can be made by calculating from figures presented in Table I.

The mean score earned for occupational Group II on the second test was found to be 20.97 (C rating), which is considered quite low and implies that the group of subjects do not have the interests characteristic of men successfully engaged in occupations listed under occupational Group II scale.

The mean score for occupational Group V on the first test was found to be 34.98 (B rating). This mean, when plotted on the Strong standard

profile sheet, falls in the shaded area of the group scale and may be considered as indeterminate so far as a significant measure of interests is concerned.

The mean score for occupational Group V on the second test was found to be 59.57 (A rating) and is significantly high. Any standard score above forty-five is interpreted by Strong (3) to mean the possession of interests characteristic of men successfully engaged in that occupational group.

The critical ratios of the difference between two means as computed for occupational Group II and Group V scales are significant beyond the one per cent level of confidence. It is highly improbable that this difference between scores could happen as a result of chance.

Discussion

The results of this investigation are fairly clear-cut. If the ability to fake scores on the *Strong Vocational Interest Blank for Men* (3) is accepted as a measure of empathy, the senior engineering students in this study demonstrated empathic ability in this paper-and-pencil test situation.

The Strong test was constructed by listing questions on hundreds of activities both vocational and avocational. Most items require a "like-indifferent-dislike" report regarding activities or topics: biology, fishing, being an aviator, planning a sale campaign, etc. The list of questions was given to successful members of a particular profession, and the interest pattern for that profession was determined by comparing the responses of the group with those of unselected men of a similar age. The weighted scoring key was then prepared to give each person a score reporting how his interests correspond with those of the professional group. Thus, in the Strong test, we have a superior example of an empirically constructed interest inventory.

Strong's inventory makes use of the fact that people in a particular occupation have roughly similar interests. This fact was demonstrated (Table I) by the results of the initial testing of the senior engineering students in that they, as a group, demonstrated a predominant engineering and physical science pattern of interest.

A second assumption basic to the Strong blank is that interests are fairly constant. The fact that the engineering students could discard their relatively constant interests and simulate the interests, as measured by this inventory, of a very different occupational group, seems to the author to demonstrate empathy with this group of people engaged in social service occupations.

It is recognized that a demonstration of empathy as measured by a paper-and-pencil test may not guarantee the transfer of empathy into empathic behavior in a true life situation. The author proposes the need for product evaluation of empathy through the use of rating scales or quality scales as a means of systematizing and organizing judgments concerning the product, in this case, of empathy. Situational tests of empathy may be designed which will provide an opportunity for observation and qualitative evaluation of empathic behavior. In the situational test the individual is placed in a standard situation, and how he reacts is unimpeachable evidence of the traits or behavior under study at that time, in that situation. The difficulty lies in inferring how he would react on other occasions and in other situations. With this limitation, along with many others, situational tests of empathy with the same subjects who demonstrate empathy

through procedures described in this research may throw further light on the transfer of empathy to behavioral situations. Certainly, tests of interpersonal behaviors are becoming increasingly significant as psychology has extended its interests of social psychology. In addition to the research interests of social psychology, tests of social behavior such as empathic behavior have major importance for selecting leaders in all fields. Military psychology has pioneered in the development of these techniques.

Summary and Conclusions

An earlier study (1) established the fact that senior engineering students could throw scores on the *Strong Vocational Interest Blank for Men* (3) from one occupational group, Group II (science and engineering vocations), to another designated occupational group, Group V (social service vocations).

As a result of a re-examination of the procedures and results of the earlier study, the author proposes to reinterpret the data from a different frame of reference—that of a measure of empathy in engineering students.

Sixty-one male senior engineering students voluntarily participated as subjects for the study. The subjects completed the interest inventory on two different occasions. The first administration was designed to measure their true or genuine interests. The purpose for having the same group of students complete the inventory a second time was to determine whether or not the subjects could discard their own interests and answer the items as [they supposed] men successfully engaged in occupations listed in Strong's occupational Group V scale would answer them.

The significance of the difference between the scores earned on the first and second administration of the inventory for occupational Group II scale (science and engineering vocations) and Group V scale (social service vocations) was found to be significant beyond the one per cent level of confidence.

The findings lead one to conclude that the subjects were capable of discarding their true or genuine interests and did simulate quite accurately the interest pattern of a very different vocational group. Thus, the engineering students ably demonstrated ability to empathize on a paper-and-pencil test with persons engaged in the social service occupations.

The findings would tend to negate the folklore on university campuses relating to the typical engineering student's inability to display social perception. In positive terms the findings would justify describing the sample engineering population as possessing social sensitivity and empathic ability as applied to the interests and attitudes of his fellow students enrolled in social science curricula.

The need for additional and various approaches to the measure of empathy is recognized. Product evaluation and situational tests of interpersonal behavior may provide further information on the validity and reliability of the paper-and-pencil measure of empathy demonstrated in this study.

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HELP WANTED!

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Presented at the 4th annual joint ASEE-Institute of Aeronautical Sciences meeting, New York City, January 30, 1957.

Is there a critical shortage of engineers and scientists in industry today?

The National Science Foundation interviewed executives of 200 companies, which employ more than half of the commercial research and development scientists and engineers on payrolls, and reported these replies:

1. Nearly half of these companies are unable to hire enough research scientists and engineers to meet their needs.
2. One out of every three companies has major or substantial shortages.
3. All companies, which reported they had been unable to fill their requirements, emphasized their need for better-qualified applicants.
4. The need for personnel is most acute among aircraft, electrical, petroleum, paper, food and primary metal companies.

Ask the top executives of any of the large aircraft manufacturers this question and all will answer a most emphatic "YES." They will tell you that a shortage exists and that the shortage is critical. The aircraft industry is wooing the engineer, both the recent college graduate and the experienced man, with a zeal rivaled only by the efforts of the big time college football coach. The paths of personnel recruiters cross and re-cross in this great manhunt. Other industries utilizing engineers are just as aggressive in the pursuit of these men. No company is spending money advertising for engineers in both newspapers and magazines without having a need. At the Georgia Division of Lockheed during 1955, we spent $1,150.00 in advertising for each engineer hired.

The Honorable Donald Quarles, as Assistant Secretary of Defense in charge of Research and Development, stated, as early as March 1955, in *Aviation Week*, "The critical shortage of engineers and scientists in America is potentially a greater threat to national security than are any weapons known to be in the arsenal of aggressor nations."

Vice Admiral Hyman G. Rickover of the U. S. Atomic Energy Commission has this to say: "It is certain that unless the number of our scientists and engineers increases at an accelerated rate, our economy will be in trouble for lack of technological nourishment."

The many articles being written and the serious consideration being given to this problem must unalterably lead even the most skeptical to only one conclusion: In our country today there exists a shortage of engineers and scientists, and the aircraft industry is one of those most critically affected.

The Reasons

The reasons for the existence of the present and contemplated future shortage of engineers and scientists are basically two-fold. First, the demand for these professional skills has increased; and second, the supply has

decreased. The progress in recent years in the field of aviation has posed new problems more rapidly than their solutions can be reached. No sooner is the sound barrier hurdled, than the problems caused by the thermal barrier are demanding solution. Missiles, with their difficulty of guidance and automatic control, have increased the demand for scientific personnel. Atomic energy and nuclear propulsion are opening unlimited opportunities for physicists and engineers. All these changes have demanded and are still demanding more personnel in the field of research and development. Engineers and scientists are urgently needed to keep it moving.

This demand can be better realized when we check our increasing requirements over the past half century. In 1900, one engineer or scientist was required for every 400 people in the industrial work force. Today, 10 engineers or scientists are required for every 400 people in the industrial work force. In the aircraft industry, the ratio is about 40 to 400. The demand for basic research and development alone has increased ten-fold since 1950.

This all points to an ever-increasing demand for engineers and scientists. Why, then, has the supply not kept pace with the demand? The reduced birth rate in the depression 1930's has resulted in a reduced population in the age group of 20–24 years today. Thus the basic source for more graduate engineers and scientists was reduced.

In the post World-War II years the graduating veterans increased the engineering and scientist force greatly. Then followed a definite decline reaching now a low point. No real quantitative figures exist to measure the disparity between the supply and the demand for engineers and scientists. A recent survey, conducted by the Manufacturing Chemists Association, indicates that in 1954 the technical labor force approximated 884,000. By 1965 there will be 1,233,000 engineers and scientists, but we will at that time need 1,680,000. The cumulative deficit by 1965 will be 457,000. The B. F. Goodrich Company, in a recent report, compares the demand and supply of scientists and engineers for the period of 1957 to 1975. Assuming a balanced supply and demand today, there will be a cumulative shortage of 100,300 in 1967.

The Aircraft Industries Association, through a survey, has stated that 4% of the aviation industrial work force were engineers and scientists at the end of World-War II. The total industrial work force at the end of 1945 was some 200,000. This indicates that the work force comprises some 8,000 engineers and scientists. The rate of growth can be estimated by using a National Science Foundation statistic of 48,000 engineers and scientists in the aircraft industry in 1954.

There is some indication that engineers and scientists now comprise 10% of the total aircraft work force. Assuming that this 10% is correct, we statistically know there are some 800,000 workers in the aircraft industry as of the close of 1956. This would give us a total of 80,000 scientists and engineers in the aircraft industry. Taking into account the influence of the Korean War and the acceleration in the aircraft industry as brought about at that time, this figure gives us an approximation of what the aircraft industry has used and may require with regard to technical manpower.

During the accelerated demand for technical people, and the shortage of specialized engineers and scientists, the aircraft industry has been able to divert basic engineering training from

one specialty to another to the advantage of the individual and the company. It is felt that this will continue to be the case and, therefore, there can be no definite categorizing of engineering backgrounds. Aircraft industries will continue recruiting their engineers from the aeronautical, mechanical and electrical engineering schools. Some chemical, industrial, and civil engineers will also be used. In the fields of science, the mathematician, physicist and metallurgist basically will cover the aircraft industry's needs.

Efforts by Industry

The aircraft industry cannot bemoan a shortage of engineers and scientists without making an effort to help itself. Let us look at some programs which are aimed toward increasing our available manpower and our technical capability.

1. It is known that our colleges and universities are predicting a steady growth in the size of their undergraduate student bodies over the next several years. The aircraft companies, therfore, must stimulate an interest in high school students to enroll in one of the engineering or science branches when entering college. We cannot wait for someone else to do the job. The spark of interest in science subjects must be struck in the early elementary school. The high school period must see this flame of interest increase for those students who have the potential of going on to higher education at a college or university. We in the aircraft industry must help arouse this interest. We can correct the prevalent student opinion that mathematics, chemistry, physics and mechanics are dry and difficult subjects, to be avoided at all costs. Television with its science programs, even of the science fiction variety, has augmented the radio and is now the most effective medium to show that science and engineering can be interesting.

As a suggestion, we might do well to copy the basic ideas of a well-established program currently in operation. The 4-H Clubs are well known in elementary and high schools and perform a valuable function. Junior Achievement is doing a similar job in the business field. Why don't we engineers and scientists benefit from these leads? Why can't there be 3-S Clubs established in secondary schools throughout the country? The 3-S could stand for "Service and Satisfaction through Science." These clubs could be the stimulant that would keep active the interest of students in science subjects during their high school days. They could be a stepping stone to higher education in engineering and science.

2. Scholarships are another means to encourage good students to strive for high academic standing. An Aircraft Industries Association survey shows that during the 1955–56 school year, 23 aircraft industry companies sponsored 404 undergraduates at a cost of more than $480,000 and granted aid to 487 graduate students at an expense of approximately $1,125,000. In addition these companies provided grants totaling $1,100,000 for specific activities.

3. Financial aid can also be given by industry by employing the cooperative program students. In general, it involves an equal distribution of the student's time between the classroom and an industry job. When a student and a company are associated throughout the five years usually required for a bachelor of science degree, there is a splendid opportunity for the company and the student to develop a rather complete knowledge of each other. These long range plans are most necessary if the basic problem is to be solved. There is a more short

range effort which is being used with beneficial results.

4. The technician must be used to the greatest possible extent. As an aid or an assistant to the engineer or scientist, the technician has a definite place and tends to relieve manpower shortage. At Lockheed, Georgia Division, we are using these technicians and draftsmen and are finding that they ease our recruiting problem considerably.

5. The industrial concerns today must be competitive, not only in pay, but must compete in their offers of training opportunities. All the larger companies now have such "on the job training programs." Training helps both the individual and the company; as a man moves up, and assumes more important work, the company gains. It is another step toward our goal in the reduction of the manpower shortage.

Help from Others

Industry, alone, cannot solve this important problem. The help of "others" is needed. Without assistance from an outside source, the technical manpower shortage cannot be overcome. What can these "others" do to help industry resolve this manpower shortage, and who are the "others"? They are our academic institutions, the faculties, the school board, the Parent-Teachers Associations and last but not least, the taxpayer who ultimately pays the bill.

Let the school faculty and the Board of Education properly prepare those students for college who are mentally equipped for higher education. Let them provide these students with the basic curricula needed for training in the sciences and engineering. We must see that our high schools offer instructions in physics, chemistry and advanced mathematics. However, our high school students cannot study scientific subjects if not enough qualified teachers are available. To get qualified instructors, teachers in these fields must be paid a salary which will enable them to maintain a living standard comparable to other professional people.

It is hoped the Parent-Teacher groups will consider this problem and support a program aimed toward a strengthening of the curriculum, increasing the living standard of our teachers, and increasing physical facilities needed to do the job.

If our academic institutions can have the PTA and the local Chambers of Commerce recognize their needed expansion, possibly the word can better reach the taxpayer. In the final solution for overcoming this shortage of engineers and scientists, the taxpayer must endorse the action. The democratic American approach to this type of problem is beginning to get underway. Once there is an acceptance that industry really is in need of the help of these "others," such help will most certainly be given. The technical pipeline then will be primed. The results will be continued advancement in our living standard and the progress which we all expect the future to bring.

SEE YOU IN PITTSBURGH

AT THE ANNUAL MEETING, JUNE 15–19

CHEMICAL ENGINEERING EDUCATION AT JOHNS HOPKINS

H. E. HOELSCHER

Professor and Chairman,
Department of Chemical Engineering,
The Johns Hopkins University,
Baltimore, Maryland

In recent months, interest in the "engineering science" curriculum in chemical engineering departments has been clearly evident in the number of symposia and discussion sessions devoted to their development. This development has its roots in the efforts of the ASEE committee chaired by Dean Grinter, culminating several years ago in the report which has become known by his name. This report, however, served only to quantify and make clear the inevitable trends forced upon engineering departments as a consequence of the ever increasing demands of the profession. At many universities, faculty and administrators alike were asking what new direction professional training must take if the individual is to contribute effectively to an increasingly complex technological society.

At Hopkins, these discussions began in 1946 and, after a hiatus of about five years, led eventually to an engineering science curriculum which was then formally adopted in 1952. The development of this new curriculum started from the agreement among the faculty of the School of Engineering that if graduates were to be adequately prepared to meet new industrial developments and problems, they needed something more than traditional training.

In June of 1956 the University graduated the first class which spent its entire college career under this new program. The following is a report on the origin, operation and results of these revisions in terms of the instructional procedure and curriculum in the Department of Chemical Engineering.

Five Proposals

Many proposals were considered by the faculty before the present plan was adopted. Some of these ideas are still under discussion, for in our philosophy of education we are inflexibly committed only to flexibility, and today's "optimum" is tomorrow's "rut." In all, five basic approaches were examined.

The first involved the elimination of engineering education at the undergraduate level. The engineering school would then be strictly a professional school, somewhat along the lines of a medical or law college to which the entrance requirement would be a Bachelor of Science degree. The advantages of this system are immediately apparent.

The second proposal was to retain the undergraduate engineering school and lengthen the period of study for the first degree to five or six years. The increased time would be used for further study of basic science, mathematics, engineering science and the humanities.

The third suggestion was that the undergraduate engineering school be retained with its traditional four year study period, but that the departmental boundaries be eliminated. Undergraduate engineering courses would be concerned solely with engineering science except for a few specialized courses available as electives in the

senior year. Intensive specialization in a particular branch of engineering would be left to the graduate level.

The fourth proposal was the so-called "bifurcated program," which has been discussed at length in the ASEE. The traditional four year departmentalized engineering program would be retained but each department would offer an option to its students. One option would be heavily weighted in favor of the scientific and technical aspects of engineering whereas the other option would stress the more technological aspects of engineering.

The fifth proposal was to organize a four year departmentalized engineering program in which each department would plan a curriculum heavily weighted toward the scientific and mathematical, eliminating most of the courses of a purely descriptive or technological nature and devising and substituting new courses emphasizing the application of the basic sciences in the solution of engineering problems within the individual departmental specializations.

Hopkins Program

The School of Engineering at Johns Hopkins elected to develop a program based on the last of these possibilities. Elimination of the undergraduate program entirely was not economically feasible for the University. Any radical change in length of study was felt to be unrealistic since for most students it is not economical to spend more than four years preparing for a career, particularly since industry apparently does not provide a sufficient incentive to warrant the additional time. Elimination of undergraduate departmental distinction met both internal and external resistance, and the school is not large enough to offer both types of curricula in a bifurcated program and yet maintain high standards in both.

Thus, it was decided to develop the "engineering science" half of the bifurcated curriculum in the School of Engineering as the most practicable, workable plan for the present. It seemed, further, that the development of such a program would constitute a continuation of the traditions of Hopkins as a pioneer in the development of graduate education. In providing all undergraduates with the same unified mathematical-analytical approach to engineering, it seemed that the curriculum would discourage the creation of an "elite" and the splintering of the student body into narrow ranks of "theorists" and "technologists." In the natural course of its evolution, the program was expected to tend toward elimination of departmental barriers and restore unity and breadth to engineering education.

The program, formally instituted in 1952, has been a success in the minds of virtually all of those associated with it. In accordance with the program, the student is led in an orderly progression from the basic sciences and pure mathematics into the engineering sciences, and from there to applications involving engineering operations.

For the first two years, he is concerned exclusively with physical sciences, mathematics, social sciences and the humanities. As a junior, he continues his study of the physical sciences and mathematics and begins study of such engineering sciences as the mechanics of fluids and solids, heat transmission and thermodynamics.

In the fourth year, he is introduced to engineering operations and is encouraged to develop his creative ability through the solution of a specific engineering problem.

Science and Mathematics

About fifty per cent of the undergraduate engineer's time is devoted to the study of basic science and mathematics.

Three full years of mathematics are required of all chemical engineering students. The first hurdle is analytical geometry, which is taken by more than half of the entering students. The rest do not have the necessary background in trigonometry and algebra and are given a refresher course in the first term. One semester behind in their normal work, they are expected to attend summer school before the sophomore year to make up the deficiency.

In the second half of the freshman year and the first half of the sophomore year, differential and integral calculus are studied. This is followed by additional calculus covering functions of two or more real variables, partial derivatives and multiple integrals.

As a junior, the student takes a required course in differential equations and infinite series and then, in the second term, selects a mathematics elective. Vector analysis, complex variables and statistics are the most frequently chosen subjects.

In the senior year, additional mathematics is recommended to those who propose to continue in graduate work.

On the science side of the ledger, three and one-half years of chemistry are a must. This includes a standard course in general chemistry and qualitative analysis in the first year, a one-term course in quantitative analysis and a full year course in organic chemistry in the sophomore year and one year of physical chemistry as a junior.

Two full years of work in physics are required. The first is a general course which includes laboratory and is given during the sophomore year. As a senior, the student chooses a second year of physics best suited to his needs and interests. Atomic physics, modern physics, and electricity and magnetism are the most commonly elected.

Engineering Sciences

Much of the undergraduate's time is devoted to the engineering sciences.

Solid and fluid mechanics have been combined into one basic course given in the junior year. Emphasis is on a unified treatment of the basic principles of mechanics. Engineering applications are used to illustrate these principles.

Among the topics covered in the course are: particle and rigid body kinematics, particle dynamics, vibrating systems, dynamics of systems of particles, rigid body dynamics, scalar and vector fields of continuum, stress, strain and rate of deformation, stress functions, applications in beam, dimensional analysis, kinematics of fluid flows and equations of motion of a viscous fluid.

At present, thermodynamics courses are offered by individual departments. Chemical engineering has such a full-year course in the junior year. During the first term, it includes material ordinarily covered in a traditional stoichiometry course. The concepts of material and energy balances are not introduced until a thorough grounding has been given in the first law of thermodynamics. In the second term, the second law of thermodynamics and the entropy principle are discussed and considerable attention is given to the fundamentals of chemical and physical equilibrium as well as the methods of calculating properties of non-ideal solutions.

In the senior year the students begin intensive specialization in their major subjects. In Chemical Engineering the classical "Unit Operations" course has given way to two which are far different. The first, a three hour course throughout the year, is at present entitled "Chemical Engineering Fundamentals" but possibly more properly should be entitled "Introduction to Transport Phenomena." Suitable texts for this course include

Volume I of the set by Coulson and Richardson, the new book by McKay, *An Introduction to Fluid Mechanics and Heat Transfer* and, most recent of all, the unpublished text by Bird, Lightfoot, and Stewart. The objective of this course is to present the fundamental equations of change covering the transport of momentum, heat, and mass as a means of illustrating the essential unity of these subjects and to develop in the student an appreciation for the values to be gained from an understanding of available analytical techniques as they apply to engineering situations.

Also in the senior year the student takes a second chemical engineering lecture course entitled "Applications." This course includes four hours of lecture throughout the year and one two hour laboratory-problem-conference session. The course begins with a brief (four week) presentation of processing methods, both inorganic and organic. When this portion of the material is covered, the student has come far enough in the "Fundamentals" course to begin using some of the information in more practical engineering problems. From this point on, the "Applications" course covers more nearly classical chemical engineering, drawing on the more basic material presented in the other course but illustrating applications to pipe line calculations, heat exchanger design, absorber performance, etc. No single text has been found to be completely satisfactory for this course. Instead, the instructor makes frequent use of material drawn from the technical literature, both in his lecture material and for assignment.

In the Laboratory, the first semester is devoted to experiments centering about the chemical engineering sciences, viz., fluid flow, heat transfer, and diffusion. At the beginning of the second semester, the students are permitted to choose one of two alternates. If they are planning to continue their education in graduate school, they are permitted to work with some member of the staff on a (or several) small scale research project, often participating in a project which is in progress. If they intend to go directly into industry, they will perform a number of the classical "unit operations" experiments.

Non-technical Subjects

Approximately 20 per cent of the curriculum is allotted to non-technical subjects. The first required non-technical subject is English writing, given in the freshman year. Its purpose is to impart a minimal degree of writing proficiency. Experience has shown that five per cent of the entering freshmen are able to meet the requirement and an absolution examination is given every autumn. If a student passes the test, he is excused from the course and selects another course in the humanities or social sciences. Those planning graduate study are encouraged to elect a foreign langauge, preferably German or French.

Selection of the remaining non-technical elective is left to the student. Psychology, political science and political economy are the most popular courses. There is also a surprising amount of interest in philosophy.

Conclusions

Although the program in chemical engineering is still changing, we believe that the soundness of its approach has been demonstrated. The key point in the program is the freedom of choice which is left to the student. The elimination of a formal requirement of an arbitrary number of credit hours and compulsory courses provides the superior student great intellectual freedom, leads to increased motivation, and provides the broad fundamental training on which he can intelligently base later specialized interests.

TABLE A

Mathematics and Science	*Credits*
Analytical Geometry	4
Differential Calculus	4
Integral Calculus	4
Advanced Calculus	4
Differential Equations	3
Vector Analysis	3
Quantitative Analysis	4
Inorganic Chemistry	10
Physical Chemistry	8
Organic Chemistry	10
Physics	18
	72
Engineering Science	
Thermodynamics	6
Kinetics	3
Mech. of Solids and Fluids	12
Chem. Engr. Fundamentals	6
Chem. Engr. Laboratory I	2
	29
Engineering Operations	
Chem. Engr. Applications	10
Chem. Engr. Laboratory II	4
	14
Non-technical Subjects	
Introd. Psychology	3
Writing	6
Speech	2
French	6
	17
Total Credits	132

TABLE B

Mathematics and Science	*Credits*
Introd. Chem. & Qual. Anal.	10
Analytical Geometry	4
Calculus	12
Elem. Quantitative Analysis	3
Advanced Calculus	6
Advanced Quantitative Anal.	5
Introd. Organic Chemistry	6
Introd. Organic Chem. Lab.	4
Physical Chemistry	6
Physical Chemistry Lab.	2
Fields of Chemistry	1
General Physics	12
	71
Engineering Science	
Fluid Mechanics	6
Principles of Mechanics	12
Elementary Statistics	3
Chem. Engr. Fundamentals	6
Chem. Engr. Thermodynamics	6
	33
Engineering Operations	
Chem. Engr. Applications	10
Chem. Engr. Laboratory	4
	14
Non-technical Subjects	
Introd. Industrial Mngt.	3
Introd. Psychology	3
Organization & Management	3
Introd. to Philosophy	3
Social Psychology	3
Personnel Psychology	3
Elementary German	6
Russian Elements	8
Speech	2
Writing	6
Elem. Political Science	3
	43
Total Credits	161

TABLE C

Mathematics and Science	*Credits*
Introd. Chem. & Qual. Anal.	10
Anal. Geometry	4
Elem. Quan. Analysis	3
Calculus	12
Advanced Calculus	6
Introd. Organic Chemistry	6
Introd. Organic Chem. Lab.	4
Fields of Chemistry	1
Physical Chemistry	6
Physical Chemistry Lab.	2
Modern Physics	9
General Physics	12
	75
Engineering Science	
Principles of Mechanics	18
Chem. Engr. Thermodynamics	6
Chem. Engr. Fundamentals	6
	30
Engineering Operations	
Chem. Engr. Applications	10
Chem. Engr. Laboratory	4
Fundamentals of Elec. Engr.	10
	24
Non-technical Subjects	
Speech	2
Writing	6
Intermed. French Reading	6
Introd. Psychology	3
Introd. Engr. Psychology	3
Advanced Prin. of Engr. Psych.	5
	25
Total Credits	154

Among the students who received their undergraduate degrees in June 1958 is a young man who, during his first year at Hopkins, proved himself capable of carrying exceptionally heavy course loads. It was possible to work out a program of study (see Table A) involving both formal course and individual work on his own part which led to the Bachelor of Engineering Science degree in three years. He is now working for the doctorate and is doing excellent work in graduate school.

Another young man, also of high intelligence and demonstrated ability, decided on graduate work soon after he enrolled for the Bachelor's degree at Hopkins. He also followed a four year program leading to the Bachelor of Science degree (Table B) and is likewise doing well in graduate school at the present time. The difference between these two programs is considerable and reflects both a difference in ability and in interest.

Students of average scholastic ability have also seemed to benefit from this curriculum. An example of such a program is shown as Table C. This program might be taken as typical of that followed by the majority of students. These 3 programs were taken directly from undergraduate records and are not in any way hypothetical. They represent actual practice.

It is the consensus of the staff at Hopkins that this type of curriculum has been quite successful. Students of better than average ability seem to benefit most as is to be expected. Generally from ⅓ to ½ of the senior class express an interest in and a desire for graduate study. In the last five years, an average of approximately 30 per cent has actually pur-

sued work leading to the Master's or Doctor's Degree. Insofar as is known, none of these men has failed to reach his objective.

The lower half of the classes (scholastically) consistently require more personal attention than they probably would need in a more standard or rigid academic atmosphere. This illustrates perhaps the most important single limitation in this program, namely, that it can only work satisfactorily under conditions wherein the faculty to student ratio is high. In the Department of Chemical Engineering at Hopkins, there are 6 full time men from the rank of assistant professor to professor and two junior instructors. The senior classes have been averaging between 12 and 15 men. While this number could increase somewhat without danger to the program such increases must be and will be small. Further, a program such as this can only flourish where there exists an active research and graduate study program. Indeed in the senior year many of the students mix with the graduate students insofar as participation in research reviews, seminars, etc., is concerned. The learning process is augmented in this way.

It is the aim of the School of Engineering at Hopkins to develop potential engineering *scientists* who can meet the challenge of an atom-powered age. We believe that the new curriculum will produce such men and will materially add to the development and advancement of engineering education.

WOULD ENGINEERING STUDENTS BE TEACHERS? (*Continued from page 754*)

Appendix A

This questionnaire was submitted to undergraduates, juniors and seniors, having grade averages of "B" or above, and to graduate students not having full time appointments. The per cent return was 38 per cent.

The table below summarizes the characteristics of those that returned the questionnaire and on whom the data is based.

	N	% of Total*
Total	245	100%
Undergraduates (U)	116	47
Juniors	49	20
Seniors	67	27
Graduates (G)	124	51
MS	83	34
PhD	41	17
Other (not summarized)	5	2
Post-degree Plans		
Industry (I)	99	40
Teaching (Tl)	25	10
Other (graduate, military)	109	44
Amount of Consideration Given to Teaching Career		
Considerable Consideration	62	25
Some Consideration	77	31
Little Consideration	73	30
No Consideration	24	10

Code

The following code was used:

Total	To
Undergraduates	U
Graduates	G
Juniors	Jr
Seniors	Sr
Masters Candidates	MS
PhD Candidates	PhD
Industry	I
Teaching	Te
Other	O
Considerable Consideration	C
Some Consideration	S
Little Consideration	L
No Consideration	N

* Note: Because of rounding error, omission, and multiple responses the percentages may not always add to exactly 100%.

Candid Comments

MANUFACTURING PROCESSES IN ENGINEERING CURRICULA

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As new developments take place, such as nuclear physics, operations research, electronic data processing, linear programming, and automation, there is a tendency for educators (and this is healthy) to endeavor immediately to introduce the development into their respective engineering curricula. With all of the evolutions that have taken place in the past ten years and all of the anticipated innovations in the next ten years, one wonders if four-year engineering curricula can possibly prevail.

In an effort to include the many new developments that are taking place, some institutions are taking a careful look at existing curricula to see if some areas of work cannot be replaced or reduced. Two of the areas have been engineering drawing and manufacturing processes.

In particular, manufacturing processes have been reviewed with a jaundiced eye by engineering educators. After all, machine shop, toolroom, welding, heat treating, and casting laboratories are extremely expensive to maintain, and capable personnel to operate them are quite difficult to find. In addition, the problems created by these labs, such as maintenance of equipment, inventory of supplies, accident prevention, and housekeeping, are troublesome. It would be so much more convenient to do away with the labs, to avoid the work involved. After all, is it not reasonable to reserve for the trade schools and the apprentice shops the instruction in the fields of manual training?

In the opinion of the writer, a thorough training in manufacturing processes is just as basic to the potential industrial, mechanical, electrical, and aeronautical engineer as calculus or physics. The engineering curriculum that removes this important training from its program would profit more to eliminate its training in chemistry or English, and I believe everyone would agree that to take away either of these fields of study would be folly.

Why and How

Manufacturing processes are the medium by which an idea or design is changed to usable goods and commodities. It is in this period of transition of ideas to material things that the majority of engineers find a life work. The engineer in training must be taught the "why" and some of the "how" of the principal processes, including metal forming and casting, metal removal, heat treating, and joining. It is important that this training does not emphasize skills, but does emphasize physical and chemical changes, mechanics, fluid flow, heat exchange, and other engineering phenomena.

The progressive engineering college administration will find complete support both from industry and trade associations in the operation of manufacturing process laboratories. The writer has yet to talk to an industrialist who has not deplored the de-emphasis of this important area by some of this country's notable educational institutions of higher learning.

At Penn State University our casting laboratory, for example, has received a great deal of support not only from industry but also from such organizations as the Foundry Educational Foundation and the American Die Casting Institute. Our association with F.E.F. has resulted in the provision of scholarships for students pursuing the casting field. It has also resulted in the provision of modern research and production facilities, the dissemination of technical information, the provision of summer employment for students and faculty, and the arrangement of engineering inspection trips.

Our association with the American Die Casting Institute, although less than one year old, has resulted in a well-rounded program of die casting education. This organization, composed of custom die casting companies, has established two scholarships at Penn State and has provided a die casting laboratory. Technical information has been made available for distribution to students and a cash prize program has been established for outstanding papers submitted on the subject of die casting. As with the F.E.F. program, summer employment and field trips are being arranged for students, and member companies of the American Die Casting Institute will stage a clinic-exhibit on campus each year for Student Chapters of ASM, ASME, AFS, and AIIE.

In a similar way, our metal removal laboratory does not emphasize just "cutting chips." Instead, the student performs an experiment. Here he gets a feel for the work, learns something of the capabilities of the process from the standpoint of surface finish, cost, time, maintenance, and so on. In a typical experiment involving lathe work, the components of force (horizontal, vertical, and radial) are recorded from a strain-gage dynamometer. The force components are then related to the geometry of the cutting tool on coordinate paper. The engineer in training thus learns the influence of back rake, clearance, and relief not only on surface finish and tool life, but on power requirements for removing metal. Here again practical help in the form of scholarships and useful data is obtained from organizations such as the American Society of Tool Engineers and other technical groups. Similar engineering experiments are conducted in our metal joining and heat treating laboratories.

As industry becomes more and more mechanized, the engineer will be expected to be able to design not only the product, but to design the process. In order to design the process effectively, whether automated, semi-automated, or just mechanized, it is imperative that his background include fundamental training in the basic processes of metal removal, metal joining, metal casting, hot and cold working of metal, and heat treating.

AT THE ASEE ANNUAL MEETING—SHIPPINGPORT

The Shippingport Atomic Power Plant of the Duquesne Light Company is located on the Ohio River, about 30 miles from Pittsburgh. It is the largest private atomic power plant in the country and generates about 60,000 Kw. It was built in cooperation with U. S. Government to further our knowledge of costs and problems associated with use of fissionable material for peaceful projects. This plant may be visited by persons attending the ASEE Meeting next June.

ACADEMIC TRAINING NEEDS IN HUMAN FACTORS ENGINEERING

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The rapid growth of the human factors field has been accompanied by considerable discussion, and some controversy, concerning the kinds of academic training which would best prepare those entering this occupation. This is not a simple problem because human factors engineering seems to cut across the traditional boundaries of scientific specialization and the departmental organization of our universities. It is apparently a mixture of pure research accompanied by a distinct effort to efficiently apply known human factors principles to the urgent needs of an increasingly complex scientific technology. It seems to require that the training and experience of several occupations be combined, somehow, into one specially trained individual who knows how to apply the knowledge of experimental psychology to design engineering, determine physiological values and parameters in systems engineering, or solve medical problems in advanced aeronautical engineering. Thus, it is not too difficult to visualize some of the problems which might be involved in training the kind of individuals who would be able to function effectively and productively in industrial situations requiring the derivation and application of human factors information. The prospects of continued expansion of interest in this dynamic applied science demand that we give adequate consideration to the effectiveness of current training opportunities in the field.

Current Opinion on Academic Training

Those who adhere to the *status quo* position feel that the individual should get an intensive specialized training in one of the human factors disciplines (e.g., psychology, physiology, mechanical engineering, etc.). If the student should then enter the human factors field after this sound basic training, he could quickly learn and readily adapt to the specific requirements of his job. Those who adhere to this view also mention that learning does not stop once the individual leaves the university. Perhaps the main advantage of this viewpoint is that little or no change need be made in current course offerings or curricula. But this conservative approach may fail to provide training which keeps abreast of current scientific advances and may fail to meet the needs of the nonacademic world.

At the other extreme, there are those who advocate a new *special training program* to provide those entering the field with the specific tools for successful job performance. Exponents of this view feel that much valuable time is wasted with some traditional university courses which have little or no relationship to the individual's prospective occupational role. This is often the position of those in industry who wish to hire someone who can

function productively with a minimum of lost time due to on-the-job training. They claim that it is too costly to convert the university graduate into a useful member of the human factors team. Also, in some cases, it is just not feasible to hire a "team" of psychologists, physiologists, anthropologists, and engineers to do the human factors work. Instead, one or two individuals with interdisciplinary knowledge and "know how" are all that are required. The disadvantage to this approach is that it is so decidedly "practical" that there may be little depth of scientific understanding on the part of the individuals so trained and the basic research so essential to the development of the field would probably suffer.

The viewpoints which are intermediate between these extremes generally relate to specific training deficiencies. It may be asserted that the mechanical engineer needs more courses in psychology, the anthropologist needs some courses in experimental design, the physiologist needs a course or two in systems engineering, or the psychologist needs a course in computer programming. Often these deficiencies seem to relate to the unique qualifications required to deal with the peculiar problems of concern only to a particular human factors group. In other cases, complaints of training deficiencies apparently relate to more general problems such as the "lack of creativity," "inability to apply" knowledge, or "failure to understand" industrial research problems.

Perhaps some of the divergence of opinion concerning the academic training needs of human factors personnel may be due to a failure to recognize the differing roles and activities performed by those currently working in the field (3, 4, 6, 7, 8, 9). If the primary job assignment involves basic or fundamental research directly related to an established scientific discipline, the training advocated by those of the status quo position is certainly most appropriate. But, if the primary job assignment involves the application of existing human factors data and principles to daily engineering design problems, perhaps the special training program approach would be more advisable. In other situations involving multidisciplinary research effort in relatively new domains, perhaps the human factors specialist could function more effectively by eliminating any specific training deficiencies in his academic background.

Current Training Needs

To clarify the basic problem of whether colleges and universities are now providing the kind of training which will adequately prepare those entering the field, a study was undertaken to determine possible training deficiencies on the part of recently employed human factors personnel. A number of modified job analyses were conducted with non-supervisory workers and, then, various levels of supervisory personnel were interviewed to determine what they considered to be the current training deficiencies among their human factors personnel. In this manner, a detailed analysis was made of the skills and knowledge which are required in daily work assignments. Those areas in which additional training might have helped in successful job accomplishment were subsequently reviewed with those in evaluative positions of management responsibility in the aircraft industry, government research installations, private consulting firms, large industrial concerns, and by some educators in various university departments. While it is recognized that there is a great deal of subjectivity and possible personal bias entering into any such an evaluation, it is hoped that this information may provide a more substantive basis on which

to plan curricula improvements than that previously available.

The results of this study indicate that the following problem areas are often sources of difficulty for the new human factors employee.

(1) Inability to produce the kind of recommendations or information which is germane or maximally useful to a particular industry. In some cases, there seems to be a preoccupation with pure or specialty oriented research of a type which is too costly in terms of the criteria of product or systems improvement. In other cases, there is apparently a lack of familiarity with the tools, equipment, processes, and procedures which are commonly found in industrial research and development organizations.

(2) Inability to function effectively as a member of the research team. In some cases, there seems to be a lack of rapport, understanding, productive inter-relationships, mutual confidence, and respect for the accomplishments of other scientific or technical team members. Too often, contributions of a team member were restricted because of the semantics, jargon, and conceptual frame-of-reference of his particular specialty.

(3) Inability to communicate the results of research or to state the research findings in such a manner as to readily permit design decisions.

(4) Failure to understand the "overall" research objectives or design problems. In some cases, there seems to be a "blind" emphasis on highly specialized components or very restricted systems engineering concepts rather than adequately defining parameters in terms of gross operational analyses. In one sense, this might be called looking beyond the immediate specifications.

How Training May Be Improved

Since the promise of scientific achievement which is inherent in the growth of human factors engineering is intimately related to the academic training provided for new aspirants to the field, such comments on current training deficiencies should be accompanied by specific recommendations as to how these conditions might be alleviated. These recommendations might best pertain to the methods and orientation of the courses to be taught and provide a specific example of a curriculum which would cover the necessary content and range of information. It should be emphasized that such recommendations are illustrative in nature and represent a compromise between varying points of view in the field. Since it is to be expected that the organization, facilities, and professorial interests in various aspects of such a program will vary considerably from university to university, the manner in which these recommendations would be implemented should provide sufficient variety to satisfy most people.

(1) The course offerings should be interdepartmental in nature. It does not seem likely that any one department could cover the wide range of subject matter needed for this field. Probably more important is the fact that interdepartmental offerings would enable the student to better understand the modus operandi and jargon of workers outside his field of primary interest.

(2) Postgraduate training for human factors engineering should have a distinct applied emphasis so that the student will be prepared to function effectively in the industrial scene. Students prepared under such a program could receive a terminal master's degree. Those who wish to engage in more basic or fundamental research subsequently could enter the doctoral program in one of the more traditional scientific disciplines. This exposure to the content and methodology of human factors engineering would help

the research specialist to better formulate his research problems so that they would prove of maximum utility to those who have to apply the results of research in industry. Equally important is the potentially fruitful cross-fertilization that would result when the research specialist returns to his scientific specialty with the new ideas, approaches, and methods found in the field of human factors engineering.

(3) There should be much greater emphasis on systems engineering, systems analysis, operational analysis, and operations research (2, 5, 10). Some understanding is necessary of the "art of making compromises," since design decisions are often successive compromises between the "ideal" of one specialty and the "state of the art" of another. Thus, human factors recommendations might range from what is considered the perfect solution to something which is considered just barely adequate. This understanding of the "overall problem" and objectives will also greatly influence the kind of research which supports these recommendations. While good scientific practice demands that we avoid making recommendations in a vacuum, it also does not mean that we should overemphasize costly, academically-oriented, time-consuming, "perfect" experiments, when all that may be needed is a "quick and dirty" answer to substitute for the design engineer's guess. In other cases, laboratory experimentation may not be capable of yielding the kind of results which could accrue from carefully controlled field experimentation or simulation. All of this infers less specialty and theory orientation and greater emphasis upon finding the most economical and effective means of achieving product or systems improvement in terms of overall operational use.

(4) There should be a continual opportunity for practice in the preparation of technical reports, staff memoranda, and illustrative sketches or drawings. Unfortunately, even the best research or design recommendations are apt to go unheeded if they are presented in such a manner as to be unintelligible to those outside the writer's specialty. Even when reduced to "basic English" the reports should not be so ambiguous as to forestall clear cut and definite decisions by others. Thus, reports should be communicative rather than highly stylized and "impressive." A technical writing, illustration, or editing staff is not always available nor able to compensate for basic misunderstanding concerning the necessity for effective communication.

(5) The student should be permitted the opportunity to get actual experience in problem solving. So much of education is of a passive, rote memory sort that the student has difficulty when called upon to translate the learned material and apply it to a concrete situation. While a thesis requirement may be of some help in this regard, the academic training should, at least, demonstrate the methods by which existing information is utilized in the creative solution of human factors problems in industry. This objective could be furthered by the use of frequent field trips, varied contract research, or the use of visiting lecturers who are actively employed in the human factors field. Perhaps some internship arrangements could be worked out with cooperative industrial concerns. Of still greater difficulty is the basic problem of teaching in such a manner so as to promote scientific creativity and effective utilization of learned skills in the solution of technological problems.

The suggested core curriculum presented in this paper (Fig. 1) represents an attempt to illustrate how a one year graduate level program could be organized which would cover the range of topics thought to be of great-

est importance by those now working in the field. Under such a program, it is felt that an effort should be made to include students with varied undergraduate preparation and work experience. Thus, students might consist of engineers, psychologists, industrial designers, anthropologists, sociologists, and other specialists who have legitimate interest in the human factors area. This would permit early classroom experience of an interdisciplinary "team" type.

In addition to the general requirement of an acceptable Bachelor's degree, the undergraduate prerequisites should include an adequate background in the biological and physical sciences, mathematics through the calculus, and probability statistics through the analysis of variance.

Not all students would take all

FIGURE 1

Suggested Core Curriculum in Human Factors Engineering *

First Semester

1. *Systems Engineering* (Electrical Engineering **). Case study approach to systems engineering, including coverage of topics such as information theory, cybernetics, game theory, operations research, servomechanics and control.

2. *General Engineering I* (Mechanical Engineering). Review of engineering drawing and descriptive geometry, elements of machine design, basic information on the operation of machines.

3. *Display and Control Relationships* (Psychology). Applied sensation and perception, signalling, multi-display problems, operator comfort and safety, vigilance problems, audiometry, acoustics, design of instruments, dials, gauges, and warning devices.

4. *Computors* (Industrial Engineering). Familiarization with data processing equipment and its potentialities, simulation, opportunities for simple programming experiences.

5. *Environmental Physiology* (Physiology). Effects on the human organism of stress, climatological factors, ventilation, heating, vibration, acceleration, noise, radiation, fatigue, illumination, clothing, and structural damage. Introduction to space medicine and basic anatomy.

Second Semester

6. *Systems Analysis* (Psychology). Group dynamics, interpersonal communication, organization, decision theory, and reliability in relation to systems components in equipment operation and maintenance.

7. *General Engineering II* (Mechanical Engineering). Survey of product information as it is related to current problems in machine design.

8. *Experimental Design* (Psychology). Methods of research in human factors engineering, efficient research design, relation of statistics and mathematics to the eduction and description of human factors parameters. Should include opportunities for actual field practice in operational analysis.

9. *Instrumentation* (Electrical Engineering). Laboratory course for familiarization with widely used measuring and recording instruments, opportunity to construct and use basic experimental apparatus, basic circuitry and use of electronic components, electronic and mechanical recording problems.

10. *Human Variability* (Anthropology or Psychology). Applied anthropometry, human limitations, personnel selection and training, social and personal factors in equipment preferences, maintenance and support problems, psychological stress reactions.

* A sub-doctoral program leading to the degree of Master of Science in Human Factors Engineering.

** Suggested university department offering such instruction. This is an arbitrary assignment since it would depend upon availability of facilities and professorial interests; for example, the university computer facilities might well be found in the electrical engineering or the business administration departments rather than in the industrial engineering department.

courses listed. If a physiologist, for example, has already taken the proposed course in environmental physiology, he could substitute additional coursework in another area, such as a course in sensation and perception. A mechanical engineer would not want to take the general engineering courses, and could elect additional coursework in psychology or physiology.

As indicated in the course listings, a program of this sort would have to be a cooperative program among several university departments. This, again, would provide the student with an understanding of the conceptual organization of knowledge, semantics, and values of those in various specializations involved in human factors engineering. This would serve to promote more fruitful and effective interpersonal relationships when working on "team" projects in the industrial work situation.

Each course should stress the application of human factors information to current problems of engineering design and operational analysis using the criteria of cost and systems effectiveness. Thus, each course should be taught in a manner such as to develop useful skills of vocational importance rather than merely knowledge which has no direct application. Knowledge for the sake of knowledge or subject matter determined by the research interests of a particular academic specialization should be reserved for those courses which are part of the preparation for the doctorate in the particular university department. To promote creative and productive approaches to human factors problems all instruction should emphasize active rather than passive or rote memory learning through individual research requirements, problem solving by use of seminar methods, case study approaches, and "team" investigation of problems. Since report writing is an essential skill, there should be a continued emphasis in all courses on the preparation of technical reports or memoranda to develop the ability to communicate or express ideas in a manner so that those outside the specialty can understand and take definitive action.

All courses would have a distinct applied emphasis. Those desiring more intensive, specialized, and research-oriented coursework could continue their studies in the doctoral programs of the appropriate university department. Those who enter a doctoral program after such applied coursework would have a far greater appreciation of the current research needs in the human factors field and the experience might serve to broaden and enrich their approach to their own academic specialty.

The courses described in the Suggested Core Curricula would, most likely, take up to five years to develop (1) and would require considerable preparation and effort on the part of the instructional staff. But, if such courses were developed, more pertinent and useful texts would soon follow. Such concentrated efforts at organizing the knowledge in the human factors field would certainly foster the establishment and development of an ever more promising and distinct applied science.

Summary

This discussion of the academic training needs in the field of human factors engineering represents an initial effort to clarify some of the major problems and offer some proposals for their solution. Since science by its very nature is dynamic and the needs of our industrial technology are ever changing, any academic training program must be continuously improved and modified if it is to significantly contribute to scientific progress.

The courses outlined in this paper are proposed in view of the results of a study concerning academic training needs in the human factors field. It is *not* suggested that these courses are already in existence in any university.

The authors wish to express their appreciation to those who gave so generously of their time and effort during the development of the concepts presented in this paper. While individual acknowledgments are certainly warranted in many cases they would be lengthy and might infer general agreement with concepts which are essentially compromises between various points of view.

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STRESS WAVE PROPAGATION SYMPOSIUM AT PENN STATE

An International Symposium on Stress Wave Propagation in Materials is to be held at the Pennsylvania State University on June 30, July 1, 2, and part of July 3, 1959, to be sponsored by the Office of Ordnance Research, U. S. Army. Specialists abroad from England, Germany, Israel, India and U.S.S.R. have been invited, in addition to specialists in the U.S., embracing the fields of high speed photography of stress waves, pulse propagation experiments, scabbing in plates, theoretical methods, viscoelastic materials, and related subjects. Joint sessions and events will be planned with the Eastern Section of the American Seismological Society, which is meeting at Penn State at the same time. Further information can be obtained from Norman Davids, Professor of Engineering Mechanics, The Pennsylvania State University, University Park, Pennsylvania, who is in charge of the program.

THE DEVELOPING PH.D. PROGRAM IN AGRICULTURAL ENGINEERING

E. W. SCHROEDER

Head, Agricultural Engineering Department
Oklahoma State University

Annual ASAE Meeting, Roanoke, Virginia, June 20, 1956.

By continuous evaluation of engineering curriculums, engineering educators have kept abreast with training requirements needed by engineers to meet their professional obligations to industry and society. The early work of setting standards for accrediting engineering curriculums by ECPD, the Hammond report, and now the Grinter report have outlined patterns for technical and social objectives of engineering education. The adoption of these standards and principles in agricultural engineering education have been influential in making agricultural engineering the profession we know it today. Our product, the agricultural engineering graduate, enjoys a demand unprecedented since the founding of the society in 1907.

The continued development of the profession will depend on a training program oriented to meet the demands of our growing technology. As technological information is developed, more training will be required. It is inevitable that this trend will continue and will lead to an expanded graduate instruction program. There is now enough experience in graduate instruction and enough agricultural engineers are employed who have Ph.D. degrees to study the graduate program objectively.

To develop information that would be helpful in formulating objectives for training doctor's degree candidates in agricultural engineering, the committee contacted industries most likely to employ agricultural engineers with doctor's degrees. To obtain information on our present status, departments granting doctor's degrees were asked for the names of those to whom degrees were granted and employment secured by the recipient of the degree.

Before 1950, only eight doctor's degrees were granted in agricultural engineering and some of these were not strictly engineering degrees. From 1950 to 1956 forty-three Ph.D. degrees have been granted. There is evidence that there was a wide variation in the type of training received for the degree. Six per cent of these students were from foreign countries and returned to their home countries. Fourteen per cent have taken positions with industry. Eighty per cent of those with doctor's degrees are on public payrolls with the following breakdown: seventy-four per cent are working for universities and six per cent for U.S.D.A. Of those working for universities, thirty-two per cent are employed by the same institution granting the degree.

Employment by Colleges and Universities

Any attempt to analyze this information or draw conclusions invites differences of opinion and interpretations; however, it is significant that eighty per cent of those with doctor's degrees are on a public payroll and more significant that seventy-four per cent are employed by colleges. An artificial demand is created for the Ph.D. on agricultural engineering faculties by accrediting groups evaluating colleges on the basis of the num-

DOCTOR'S DEGREES GRANTED IN AGRICULTURAL ENGINEERING BY SCHOOLS

Schools Offering Ph.D. Degree Training	Number Granted	
	To June 1956	'56 to '58
Iowa State College	15	5
Missouri University	2	2
Michigan State University	22	19
Cornell University	12	4
Oklahoma State University		1
University of California		
N. Carolina State College*		
University of Minnesota*		
Purdue University*		
Total	51	31

* Authorized to grant Ph.D. degrees since 1956.

ber of staff members with Ph.D. degrees, college administrators basing promotions on degrees or limiting promotions for lack of degrees, and organized groups within college faculties judging an individual's ability to take responsibility on the basis of the doctor's degree. Such creation of demand is superficial and eventually will mean that a Ph.D. degree becomes mandatory for an agricultural engineering staff member.

As this type of demand for advanced degrees increases, an attitude often develops among students that the training is secondary just as long as they get the degree. This attitude, allowed to overly influence, could be more disastrous to the development of the profession than our early experiences with the B.S. degree. With the present high salaries for students graduating with a bachelor's degree, the long training required for a Ph.D. degree is not conducive for attracting the best students for graduate work. A mandatory requirement of a doctor's degree to qualify for college faculties is not conducive for getting men with industrial experience for teaching. All of these factors have a tendency to develop agricultural engineering faculties composed of professional educators distinctive from the professional engineer. This would be unfortunate for the profession and the college staff. Presently, we enjoy a free flow of agricultural engineers from industry to college staffs and vice versa, to the advantage of industry, college staffs, and the profession. With the present trend, unless more agricultural engineers with doctor's degrees are employed by industry, it will become increasingly difficult to employ staff members with industrial experience.

Employment in Industry

An attempt was made to obtain an expression from industry on their requirements for advanced training of agricultural engineers. Three machinery companies, two trade associations representing building material manufacturers, two companies fabricating and marketing steel buildings for farm use, one consultant, and one electrical equipment manufacturer were contacted. These groups were asked two questions: one, "Keeping in mind a salary potential that would warrant a student spending three years in college beyond a bachelor's degree, would your industry hire agricultural engineers with a Ph.D. degree?" Two, "If yes or maybe in the future, what kind of training could your company use . . . highly specialized training in science and research or broad technical training, including humanities and economics." Most of them replied to these questions by writing a letter.

The consensus was that industry is

EMPLOYMENT DISTRIBUTION OF AGRICULTURAL ENGINEERS WITH PH.D. DEGREES

Employer	Number	
	50–56	56–58
School granting degree	13	3
Other Schools	25	20
U.S.D.A.	3	4
Industry	7	1
Foreign students returned to home country	3	3
Total	51	31

not interested in hiring agricultural engineers with Ph.D. degrees at the present time. However, it is interested in employing engineers for a specific specialty or men whose thesis or specialization bears directly on a particular problem in which the company is interested. Industry expects a man with a graduate degree to have more capacity for work than one with a bachelor's degree and salaries are commensurate with accomplishments. With one exception, specialized training was preferred over a broad training.

The reports from the universities show that eight of the fifty-one agricultural engineers with doctor's degrees are employed by industry. The distribution of these eight are as follows: three are employed with two farm machinery companies, one with a processing company, one with a steel fabricating company, one with a manufacturer of heavy construction equipment, one with a sewing machine company and one consultant. This number is too limited and too varied in type of employment to draw any conclusions except with further study regarding the type of work these men are doing.

Advanced Training and the Grinter Report

A presentation of this nature would be incomplete without reference to the Grinter report. Previous engineering reports made little or no reference to graduate study. The growing importance of graduate study in engineering is indicated by the fact that seven of thirty-five pages of the Grinter report were devoted to graduate study. The report emphasizes that graduate study must be on an individual basis. The program should be selective regarding students and flexible to allow individual initiative. Because of the expense and nature of the training, it cannot involve *large numbers*. It also emphasizes the need for an understanding of science and the ability to use mathematics.

The following are a few pertinent quotations from the Grinter report: "The majority of good doctoral prospects will lie within a much narrower fraction, perhaps the top tenth or less, but those students who make top grades by rote learning in an undergraduate program may still be poor prospects as graduate students. The attitude that most students deserve a chance at graduate study . . . may be damaging in its effect upon those who are well qualified for graduate study as well as those that are not." "In engineering, one of the required studies is almost invariably advanced mathematics, for the graduate student requires additional mathematics to conduct advanced work and to convey his scientific explanations to others. On the level of the master's degree, anything less than a full-year course in mathematics beyond elementary differential equations appears to be inadequate for effective understanding and use of the scientific principles on which advanced work in engineering will almost inevitably be based. The doctoral level demands at least an additional year of mathematics." On the importance of science, "A comprehensive knowledge of mathematics alone has little practical utility for an engineer unless it is employed to effect an equally profound understanding of those physical, biological, or engineering sciences which are the necessary background for creative design."

There is a real opportunity for the agricultural engineer with advanced training, properly planned and administered. The industries supplying agriculture with tools of production will need men trained as outlined in the Grinter report. To document this, are quotations from letters received

from men in industries employing agricultural engineers. (1) "We are looking for someone who can do a specific job for us, and it would depend to a great extent on the individual and his specific speciality and what his contribution could be to our company. . . . We would be more interested in the individual with a Ph.D. degree if his curriculum has been in highly specialized training in science and re-research." (2) "I am not sure that a young man with a Ph.D. degree without any experience would be employed by companies such as ours but believe men with advanced training are sorely needed. The science of designing functional buildings and equipment has reached a point where it is beyond the student with just an undergraduate training." (3) "Since industry pays for recognized values, we expect a man with a graduate degree to be able to do work beyond the capacity of one with only a bachelor's degree. However, under present circumstances, it is largely up to the individual to see the opportunities for him to apply his talents, and to take the initiative in such circumstances. . . . It is most difficult to pursue advanced technical studies on either a home study or spare time level. This is not true of cultural subjects, i.e., the humanities and economics. For this reason, I personally feel that the overall advantage appears to lie along the lines of devoting much of the year's residence study to subjects of a scientific and technical nature." (4) "We are not interested in agricultural engineers having a Ph.D. degree unless the topic of their thesis or their specialization bore very directly on one particular problem in which we were interested. . . . We do have one man in our department having a master's degree and are just now employing a second man holding a master's degree, but in both cases their work has to do with instrumentation and especially the application of electric strain gauges to farm machine problems."

In conclusion, the advanced training required and for which there will be a demand in the future is no different for agricultural engineering than for other engineering fields. In some engineering schools, the continuance of a general education on the graduate level is considered important for those who plan to become engineering teachers, but for those who plan to take their place in industry, the need is for men trained to use the sciences and mathematics to do a specific job. Consequently, Agricultural Engineering Departments should be associated administratively with other branches of engineering and science that will permit the candidate, for an advanced degree in agricultural engineering, to concentrate on course work in science and mathematics while working on a specific problem in the Agricultural Engineering Department under the supervision of the agricultural engineering staff.

Agricultural Engineering Departments of the land grant colleges are especially well equipped to provide graduate training as outlined by the Grinter report. The teaching loads of graduate faculty are low. Through active and well financed research projects of the Agricultural Experiment Stations, new information is constantly being developed and fed in as it becomes available; also, proper facilities are provided and a favorable environment is developed so that graduate faculty members, in line with the Grinter report, "pursue those activities of research, development, and creative design which mark the life of a graduate school teacher."

MECHANICS DIVISION BULLETIN EXECUTIVE COMMITTEE

P. F. Chenea, Ch. 1959	A. Higdon..... 1960	J. O. Smith..... 1961
R. L. Flanders... 1959	L. A. Smith..... 1960	E. J. Marmo..... 1962
F. L. Singer..... 1959	D. R. Carver..... 1961	E. P. Popov..... 1962

Secretary of the Mechanics Division: Major Vincent S. Haneman, Jr., Department of Aeronautical Engineering, Air Force Institute of Technology, Wright-Patterson AFB, Ohio.

Editor: Arthur W. Davis, Department of Theoretical and Applied Mechanics, Iowa State College, Ames, Iowa.

MECHANICS DIVISION PROGRAM AT THE ASEE ANNUAL MEETING, JUNE 15-19

Monday, June 15, 1959

12:00 Noon Luncheon, Executive Committee of the Mechanics Division.

2:00 P.M. Conference

Presiding: Kenneth C. Deemer, Chairman, Department of Engineering Mechanics, University of Kansas, Lawrence, Kansas.

Theme: "A Discussion of the Follow Up Committee Report on the Mechanics of Fluids; Fluid Mechanics as it is being taught and as it should be taught."

Speakers: Joseph W. Howe, Professor and Head of Engineering Mechanics and Hydraulics, State University of Iowa, Iowa City, Iowa.

George F. Wislicenus, Professor and Director of the Garfield Thomas Water Tunnel, Pennsylvania State University, University Park, Pennsylvania. (No titles to individual papers; each speaker will speak in the area of the conference theme.)

Tuesday, June 16, 1959

12:00 Noon Luncheon Mechanics Division

Presiding: Paul F. Chenea, Professor of Electrical Engineering, Massachusetts Institute of Technology, Cambridge 39, Massachusetts; Chairman, Mechanics Division, A.S.E.E.

Speaker: George A. Gullette, Professor and Head of the Department of Social Studies, North Carolina State College, Raleigh, North Carolina.

Title of Talk: "The Need for the Humanities in Engineering Education."

2:00 P.M. Conference

Presiding: Robert G. Valpey, Major, U.S.A.F., Department of Mechanics, U.S.A.F. Academy, Denver, Colorado.

Theme: "What and How in Undergraduate Mechanics Instruction."

Speakers: Raymond L. Bisplinghoff, Professor of Aeronautical Engineering, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

Title of Talk: "The Requirements of a Modern Curriculum in Undergraduate Mechanics."

William J. Hall and John D. Haltiwanger, Associate Professors of Civil Engineering, The University of Illinois, Urbana, Illinois.

Title of joint paper: "Statics and Dynamics in Undergraduate Civil Engineering Education."

RECOMMENDED CHANGES IN THE UNDERGRADUATE COURSE IN MECHANICS OF MATERIALS

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Presented at the June 1958 Annual Meeting of ASEE, at University of California, Berkeley. Recommended for publication by the Mechanics Division.

Introduction

The subject of mechanics of materials deals with the response of solid deformable bodies, such as structural or machine parts or members, to the action of external forces called loads. The usual response of the body or member as it deforms is to resist the load and preserve a state of equilibrium. Sometimes the state of equilibrium is attained only after considerable vibrational motion of the body occurs, especially if the loads are applied dynamically. Thus, the subject deals with external and internal forces, deformations of the member, and properties and internal structure of the material of which the member is made, when the load-resisting member is used in a given physical situation. It should be understood that the subsequent discussion deals with a first course in mechanics of materials for engineering students.

The problem considered in this subject has usually been that of determining a relationship connecting the loads acting on a member made of a given material with the deformation of the member (or some other quantity, such as stress, that is known to be directly related to the deformation) and the properties of the material. And in the method of obtaining the desired relationship, simplifying assumptions are usually made which restrict the solution to an ideal body (often called a model) in which the material is considered to be perfectly elastic, continuous, homogeneous, etc. This method leads to the mathematical theory of elasticity and by introducing certain additional simplifying assumptions or approximations we obtain the relationship as usually presented in the subject of mechanics of materials. In other words, the subject of mechanics of materials is often considered to be a watered-down theory of elasticity. The method usually employed in treating the subject of mechanics of materials frequently serves a very useful purpose, but as will be discussed later, it is decidedly inadequate for attacking many important engineering problems involving load-resisting members: The method needs to be broadened as suggested in this paper.

Furthermore, the relationship obtained usually is between loads and elastic stress in the member or between loads and elastic deflection of the member, and the safety of the member is assured by selecting a working or safe value of stress (or

of deflection) for the given material and limiting the loads to values that will not cause a stress (or deflection) greater than the working value. The subsequent discussion will indicate that this concept of safety is also inadequate for present-day problems involving load-resisting members.

Main Objective

The principal aim in the study of mechanics of materials should be to determine a relationship connecting the external load and the deformational behavior or response of a deformable body or member under a given set of service conditions. But this objective cannot be attained unless a complete description of the response of the member to load is known for a range of values of loads from small load to the ultimate load. Often this range will lead from elastic behavior at small loads to inelastic behavior (sometimes fracture) at larger loads. This whole range of response is usually needed in order to discover the condition or conditions (later called mode of failure) that determine the limiting value of the load that the member can resist without having its load resisting function destroyed in the given service or operating situation.

The first part of the problem of mechanics of materials, therefore, is to determine the response of a member of a given shape, material and environment (temperature, etc.) to a given type or condition of loading such as static loads, cyclic loads (repeatedly applied loads), impact or blast loads, etc., or to a combination of such loads. And this response must be known from the time the load is small up to the time the load becomes so large that the member can no longer resist the load and satisfactorily fulfill its function in the structure or machine of which it is a part.

Modes of Failure

When this complete description of the response of the load resisting member is known for the given set of conditions, it will be found that at a certain set of values of the load and of deformation a particular behavior, called a mode of failure, will cause the member to fail in its performance of resisting the load on the structure of which it is a part. Some well known modes of failure are as follows:

a) Excessive elastic deformation; if the load is cyclic or if suddenly applied, the elastic deformation may lead to objectionable vibration.

b) Permanent deformation caused by the load exceeding the elastic limit load, that is, the load at which the most stressed fiber reaches the elastic limit of the material.

c) Fracture of the member, such as occurs in brittle materials; or fracture in ductile metals when conditions are such as to produce fracture; as, for example, when repeated loads are applied, or when static loads are applied rapidly in combination with low temperature and tri-axiality of stress.

d) Collapse of the member under unstable conditions of elastic or inelastic buckling, sometimes under conditions of elevated temperature.

e) Collapse of the member when the so-called fully plastic load occurs, as for example in a simply supported beam when a plastic hinge occurs at the section of maximum bending moment (see example in Part IV).

We have thus far described briefly the nature of the response of a deformable body or member to the effect of external load as a relationship between the load and the deformation. We wish to explain further the connection between mode of failure and the load-deformation relationship. If we think of this relationship as mathe-

matical, we must sometimes express it with two or more equations. One equation is required to describe the behavior for elastic conditions and one or more additional equations are required to describe the behavior for other conditions, let us say for inelastic conditions.

For convenience we shall first examine this relationship for the response in which inelastic (plastic) deformation can occur in the member. The load-deformation relationship, like all mathematical relationships, must be interpreted physically in order to obtain the significant facts concerning the physical behavior of the member with regard to the function it performs as a load-resisting member. The mode of failure, as previously defined, helps us to determine from the load-deformation relationship the particular values of the load and of the deformation that occur at failure. Therefore, if we are interested in computing the values of the load and of the deformation at failure, we must be sure to use the particular equation that represents the load and deformation for the failure conditions.

In determining the value of the load at failure it is often convenient to obtain it from a relationship between the load and some quantity other than the deformation. For example, let a slender straight member be loaded axially in compression by a load P. If we determine the load-deformation relationship it will be seen that there occurs a sudden change in the curve at which the load remains almost constant while the lateral deflection continues to increase. This load is the buckling load P_E and is given by the familiar Euler equation $P_E = \pi^2 EI/l^2$, where E is the modulus of elasticity, l is the length and I is the least moment of inertia of the cross section of the member. This equation does not relate the loads and the lateral deflection of the column, but nevertheless it does predict the load at which large lateral deflection occurs, and consequently it predicts the failure load.

Later in this paper another example will be given in which an equation that relates the load and the bending stress can be used to predict the load at which the deflection of the beam will become very large and hence will constitute failure.

In the foregoing discussion it has been assumed that a knowledge of the physical properties, sometimes called the resistive behavior of the material, has been available. Otherwise the determination of the mode of failure, and hence the load-resisting behavior of the member, is not possible.

It should be pointed out that sometimes more than one mode of failure can occur in the same member. They are said to be competing modes of failure. In such members a careful examination of each mode of failure must be made.

Traditional Approach

To contrast the proposed approach to mechanics of materials with the traditional approach, let us return to the discussion of the commonly used method given in the introduction to this paper.

Let us suppose that a member of ductile metal is subjected to static loads at ordinary temperatures. As frequently taught at present the subject of mechanics of materials would deal only with the elastic response of the member, whereas under many service conditions the load resisting capacity of the member is not reached until the member has been given considerable inelastic deformation. Hence, a rational approach to the determination of the ultimate load

Δ = Maximum deflection of beam.

M = Maximum bending moment of beam.

Δ_e = Maximum deflection of beam at beginning of yielding.

$M_e = \sigma_y \frac{I}{C}$ = Maximum bending moment at beginning of yielding.

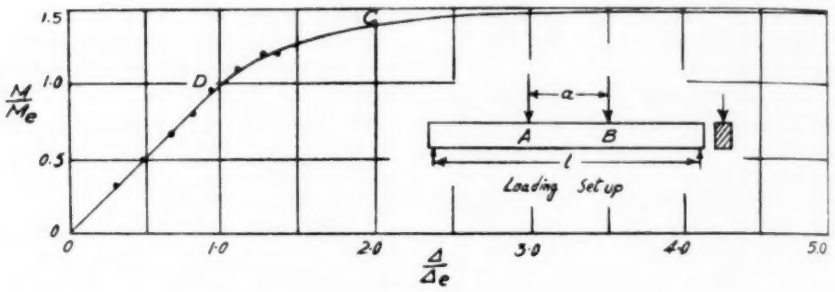

FIG. 1a.

and thus to the working load requires that an analysis be made that includes the effects of the inelastic behavior. Thus in such problems we need to broaden the scope of our theory to include in the analysis the inelastic behavior. However, instead of broadening our theory we often attempt to solve such problems for the ultimate or limiting value of the load by making use of the elastic theory and introducing fictitious quantities such as modulus of rupture, fictitious moment arms, equivalent moments, etc., that cause the equations obtained from elastic theory to give results consistent with ultimate loads as determined from experiment. The use of such a procedure invariably leads to confusion, especially about the safety of the member, because it does not contribute to an understanding of the physical nature of failure of the member.

Examples similar to the preceding could be given that involve failure by brittle fracture, creep at elevated temperatures, buckling, etc.

Example of Proposed Approach

In order to interpret in greater detail the proposed approach in the subject of mechanics of materials, let it be assumed that we are dealing with a rather simple and familiar set of conditions, namely, let the member be made of so-called ductile material; also, let it be of such a shape and be subjected to a type of loading and to a temperature that will allow the member to undergo general yielding (rather than highly localized yielding that might result in a brittle fracture). Furthermore, it will be assumed that the function or service of the member is such that the member may be given considerable inelastic deformation before its maximum load-resisting capacity is reached.

These conditions are satisfied approximately in various structures by a straight member of constant cross section, made of hot rolled mild steel, when the member is subjected, at so-called room temperature, to a static (gradually applied) load. And, to be specific, let us assume that the member is to be used as a simple beam of rectangular cross section, simply supported at its ends and subjected to two concentrated loads located symmetrically as shown in Figure 1a. The beam is also supported laterally to prevent twisting or buckling.

Our first objective or step is to observe and describe the behavior or response of the member to the loads throughout the whole range of loading up at least to the load that causes failure under the service conditions considered. In Figure 1a is shown the curve ODCF relating the load (in terms of the maximum bending moment M) and the maximum deflection Δ of the beam. The equation of OD and of DCF can be derived by making use of the tensile and compressive stress-strain curves and by assuming that plane sections remain plane. The analysis is carried out for stresses and strains below the elastic limit, and is represented by OD, and for stresses and strains above the elastic limit, the results are represented by the curve DCF. It is important to note here that the curve ODCF is composed of two parts, each represented by a different equation. The analysis is within the scope of mechanics of materials and is not complicated by the use of principles beyond those ordinarily taught in the course. The ordinates of ODCF are made dimensionless by dividing M by $M_e = \sigma_y I/c$ which is the resisting moment when the extreme fibers of the beam are just beginning to yield as shown at D in Figure 1a. Likewise, the abscissas Δ are divided by the maximum deflection Δ_e that occurs just at the beginning of yielding in the beam in the extreme fibers when $M \doteq M_e$. The straight part OD represents the elastic behavior of the beam from zero load to the elastic limit load M_e. The curved part DCF represents the load and deflection during the elastic-plastic behavior, that is, while the yielding spreads gradually inward towards the neutral axis after starting at the outer fibers as represented by the point D. In Figure 1b is shown the portion of the beam between the points A and B when the load and deflection are represented by the coordinates of point C. The sharp pointed wedges as seen on the top and side of the beam are Lueder's bands. The small dark rectangles on the top and side of the beam are wire resistance strain gages and the numbers above each of them represent the strain at that gage, where 1.00 is the elastic limit strain. Eventually, after a great amount of deflection, the load M will approach asymptoti-

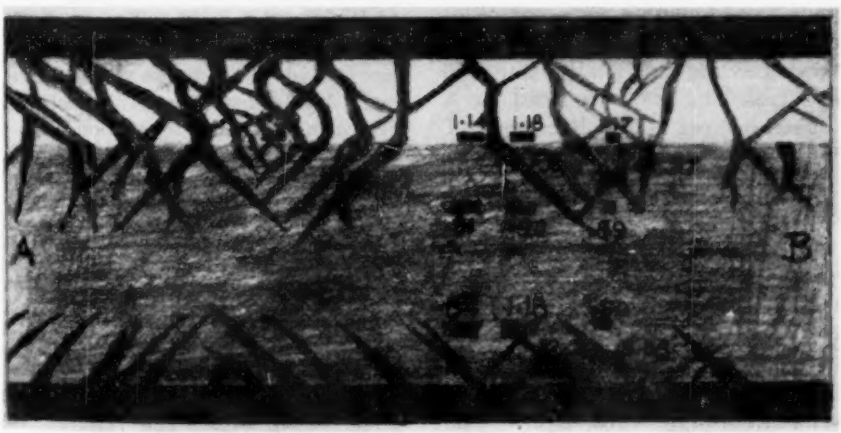

FIG. 1b. Mild steel straight bean with rectangular cross-section showing strain levels in a field of heterogenous yielding.

cally a value equal to 1.5 times M_e. This is the so-called fully plastic load and represents, for most practical purposes, the ultimate load for the beam, since the deflection that corresponds to 1.5 M_e is very large when compared with Δ_e.

This example demonstrates the following:

The deformational response of this beam to the load is given in Figure 1a by ODCF, which must be described mathematically by two equations; the first equation is of the straight line OD that describes the elastic response and the second equation is of the curve DCF that describes the inelastic response of the beam up to the fully plastic load. The equation of the curve DCF gives as a limiting value (fully plastic value) of the load $M_{max} = 1.5\ \sigma_y I/c$. This value of the load must be used in determining the safe or working load for the beam. It should be pointed out that, although the safe or working value of the load M may be less than M_e and hence may lie somewhere between O and D within the elastic response of the beam, we cannot use the equation of OD exclusively to establish the safe or working load for the member. In other words, a complete description of the deformational response of the member is required for the purpose of establishing the safe load in a rational manner. This description of the response must include the condition or conditions at failure of the member.

It should be emphasized that the equation $M_{max} = 1.5\ \sigma_y I/c$ does not relate the load to a deformation, but it does determine the value of the load that corresponds to a very large deflection, which constitutes failure of the beam in most structural or machine members that are subjected to bending.

Summary

1. The scope of the subject mechanics of materials or mechanics of deformable bodies as given in a first course for engineering students should be broadened by including various deformation responses in addition to the elastic response of the body or member.

2. An analysis leading to a relationship between the load and the deformational response should begin with a determination of the possible modes of failure, and the relationship should be applicable to the whole range of behavior from low loads to the ultimate or failure load, so that the ultimate load may be determined as a basis for indicating the safety of the body as a load-resisting member.

3. The foregoing statement means that one important use or purpose of the analysis is to obtain the basis for design of the member but only for insuring safety in its resistance to loads. In other words the subject should carry the student to the point where he sees the use of the subject to the engineer; in addition this means that the common method of insuring safety by specifying working (safe) stresses should be abandoned except for the restricted case where the failure load occurs within the range of elastic response of the member. Too sharp a line is sometimes drawn in this subject between analysis and design. They should not be thought of as separate operations, but rather as different aspects of the same problems. Furthermore, design considerations give strong motivation to the student.

4. The method of attack in the analysis gives strong emphasis to the physical environment in which the member is used, in order to understand the deformational response of the member and also of the material of which the member is made. This

means that more knowledge of the internal structure and properties of materials should be introduced in the subject of mechanics of materials, particularly in determining the probable modes of failure. Furthermore, inasmuch as this knowledge for various service conditions is at present inadequate for satisfactory results in some problems (brittle fracture type of failure, for example) the teacher of this subject must continually keep abreast of and participate in, if possible, the analytical and experimental investigations on this subject.

5. The proposed modification discussed in this paper can be carried out without abandoning any of the topics now taught in the course. However, we have concluded that the teaching of more than one techniques of the differential equation method of finding the elastic deflection of beams should be discontinued. Also, less emphasis may be placed on statically indeterminate members; this topic perhaps should be considered to be more in the field of structural mechanics than in the field of mechanics of materials.

ELECTRON MICROSCOPE SUMMER COURSE AT CORNELL

Cornell University announces the annual "Summer Laboratory Course in Techniques and Applications of the Electron Microscope," which will meet this year from June 15th to July 3rd.

The course is planned to meet the needs of senior research workers in the field of electron microscopy. The registration is limited to a small group, to provide ample facilities for extensive laboratory work in special fields, at introductory or advanced levels depending on previous experience.

Requests for information and applications should be addressed to Professor Benjamin M. Siegel, Rockefeller Hall, Cornell University, Ithaca, N. Y.

NEW DEGREES AT MICHIGAN

Approval for two additional degrees of instrumentation engineer and naval architect in the two-year professional programs in engineering at The University of Michigan was given by the Regents in December.

The additional degrees were requested by the Executive Board of the Graduate School. At their October program, the Regents had given approval to this new two-year program and at that time had established ten different degrees.

DISCUSSION OF THE FOLLOW-UP COMMITTEE REPORT ON MECHANICS OF SOLIDS

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Presented at the June 1958 Annual Meeting of ASEE, at University of California, Berkeley. Recommended for publication by the Mechanics Division.

In discussing the Report on Mechanics of Solids, my point of view is that of a teacher of courses for which engineering mechanics is prerequisite. Thus I have been in a good position to study the product of courses in statics and dynamics which I believe are typical of those in most engineering colleges. I must add, however, that I have not taught mechanics myself.

The bulk of the committee report comprises an outline of the entire field of solid body mechanics. This makes clear the extent of the whole field but does not suggest what areas should be treated in undergraduate curricula. Neither does it imply in any way that a series of courses should follow the given outline. While the outline of the field is certainly useful, the really important part of the report to me is contained in a few sentences on the first page. At the risk of boring some of you who have already studied the report carefully, I would like to read these important sentences:

"The study of Engineering Mechanics contributes in two important ways to the engineering curriculum. First, it offers an opportunity to introduce the engineering methodology, and second, it offers an opportunity to understand the laws of motion.

"An engineer must be able to observe the physical world and abstract from it a simplified model relevant to the questions to be answered. He must then analyze the model to obtain the desired answers using the appropriate facts, techniques and physical principles. Finally, he must then relate the answers obtained from the analysis of the model to the real physical problem. Engineering Mechanics is one of the first subjects in the curriculum which offers an opportunity to develop the skill of the student in this methodology. Furthermore, Engineering Mechanics is a desirable vehicle for the introduction of this methodology since its models are relatively easily understood by the beginning student.

"The heart of a treatment of Engineering Mechanics is Newton's Laws of Motion or equivalent statements, which can usually be stated precisely in very brief form. The remainder of the courses in Engineering Mechanics is not a question of more subject matter, but rather a question of developing a better understanding of these laws and skill in their use in solving engineering problems. In short, the test of a good course in Engineering Mechanics is not really a question of what subject matter has been included but rather one of how good an understanding has been imparted to the student and how facile the student is in applying the laws of motion."

I agree with this statement wholeheartedly. I believe that every teacher of engineering mechanics should study it carefully and ponder it in relation to his own courses because, based on my own admittedly limited experience, I do not believe that present day mechanics courses

come up to the standard specified in the report. Typically I find that students who have completed the elementary courses in engineering mechanics do not have what I consider an effective understanding of mechanics and they are not good at applying the laws of motion.

To explain my point I wish to describe three fairly simple problems in mechanics which I have used a number of times with students who had completed courses in mechanics and which caused these students a lot of trouble.

Problem 1

The first problem (Fig. 1) concerns a stiff rectangular steel plate supported by upright members a-a and carrying an off-center load W. The plate slips easily between the uprights but the clearance is not enough to allow appreciable tipping. The plate is held up by four pins at the corners. The holes in the plates and in the uprights are not located precisely but clearances are such that the pins all slip in easily during assembly. We wish to know the maximum shear load in terms of W that any one of the pins may have to support. This was given as a two-hour closed book quiz.

Consistently I have found that about 60% of the students miss the point of this problem. The poorest students introduce horizontal and vertical components of reactions at all four pins (8 unknowns) and then write moment equations about every conceivable axis and finally expire in a morass of algebra. Students who are slightly more acute—typical of the middle of the class—discover that the conditions of equilibrium must be supplemented by further information and then proceed to assume that because of symmetry about the horizontal axis the upper and lower pins share the load equally.

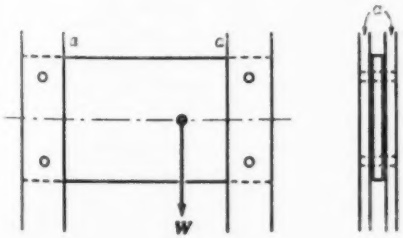

FIGURE 1

Only some 40% start by using what we tend to call common sense but which in this case is really a consideration of the necessary geometric relations. These students, of course, are the ones who see that in the absence of deflections the plate can be supported by only two of the pins and that depending upon the details of the misalignment of the holes any one of the six possible pairs can do the job. However, most of these better students overlook the possibility of static indeterminacy in even the case of two-pin support. That is, for example with the plate hanging on the two upper pins, they ignore the possibility of horizontal forces at the upper pins. Only the very exceptional student, one in ten or twenty, sees by himself the full enormity of the situation, that one needs to know in detail the entire geometry before the forces can be determined exactly.

What I believe to be wrong here is that the typical treatment of statics tends to focus for too long a period on cases which are completely determinable by the conditions of static equilibrium and thus the student learns about statically determinate cases but not enough about the conditions of static equilibrium to really appreciate what they cannot do as well as what they can do. What we tend to do at present in this area is a little like trying to teach electric circuits using only one of Kirchhoff's

two laws for a whole semester before introducing the other law. I urge that much more emphasis be given in the early teaching of engineering mechanics to the necessary conditions of geometry and of compatibility as well as to the conditions of static equilibrium. My belief is that the most effective teaching device for this purpose is a series of realistic problems where the student must apply these conditions by himself in a variety of situations including ones that are statically indeterminate.

Problem 2

The second problem I wish to discuss is shown in Figure 2 and concerns a proposal for an inertia starter for an internal combustion engine. It consists of a flywheel geared to a shaft which can be connected to the engine by means of a clutch not shown. With this clutch disengaged the rotating parts of the starter are run up to a high speed by a hand crank. Then the hand crank is disconnected and the clutch is engaged so that the energy stored in the rotating gears and flywheel is dissipated in starting the engine. The student is asked to find the torque available at the starter shaft and the reaction torque at the mounting flange in terms of the rate of deceleration. This problem also was given as a two-hour closed book exam.

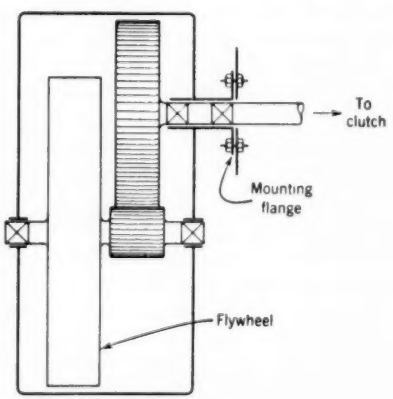

FIGURE 2

I find that the majority of my students can find the shaft torque successfully. Some do it by introducing the forces of action and reaction at the gear-tooth contact and applying Newton's law to each of the shaft assemblies. Others do it by equating the time rate of decrease of stored kinetic energy to the mechanical power output of the shaft.

Finding the torque reaction at the flange is, however, much more difficult for the students. Only the most able students come to the correct result, and do it by considering carefully and correctly the forces of action and reaction at each of the bearings. There are always a few students who conclude that there is *no* reaction torque at the flange. But the majority say that obviously from the law that every action has an equal and opposite reaction, the torque at the flange is equal and opposite to the shaft torque, which, of course, is not so.

The chief thing I want to point out here is the common misconception of action and reaction. I suspect that the trouble goes back to misteaching in high school physics, but I am also suggesting that engineering mechanics teachers could do more to clarify the real meaning of Newton's law of action and reaction by giving some problems where misuse of the law would cause serious error, as in this example.

Incidentally, the elegant way to find the flange torque after the shaft torque has been found is to invoke the principle that the sum of the external torques acting on a system is equal to the time rate of change of angular momentum of the system, but I have never had a student do it this

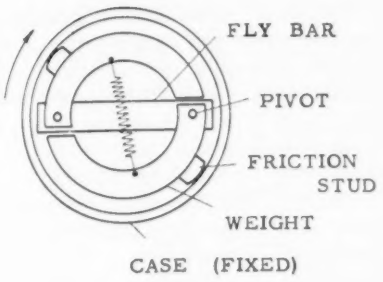

FIGURE 3

way. This puzzled me until I explored a number of standard texts on engineering mechanics and found that this powerful and fundamental principle receives very little attention —and then often it is buried in a discussion primarily about impulse. While I do not urge the inclusion of this principle in an elementary course in dynamics, I would place it ahead of some of the special methods that often are included.

Problem 3

The third and last of my problems showing deficiencies in mechanics education is illustrated in Figure 3. This is the speed governor in the ordinary dial telephone. It is what keeps the impatient subscriber from forcing his dial back more rapidly than our electrical friends in the telephone company want it to go.

The governor consists of a fly-bar coupled through gears to the finger wheel and having weights pivoted at its ends. As the mechanism runs down under the action of a spring, which supplies an essentially constant torque throughout, the weights press friction studs outward against the case, thus providing a retarding torque which depends upon the speed. The spring tending to hold the weights in is fastened at points coinciding with the corresponding centers of mass. The spring is hooked in with initial tension, and since the possible radial movement of the weights is very slight, the tension remains substantially constant. Except for the friction afforded by the governor, the mechanism is essentially unloaded during its rundown. Desirable characteristics of the governor are to have speed as nearly independent of coefficient of friction as possible and of force applied to the dial. In a one-week assignment for outside work, the student is asked to investigate analytically to see how well the governor can perform its function.

The analysis of this governor is a bit complicated; there are several unknowns to be eliminated, there is some trigonometry to be kept straight, and the differential equation in angular velocity which turns up is non-linear, although separable. But these things are not what give the students their basic trouble. Rather their difficulty is that a year or two after they have studied the dynamics of the plane motion of a rigid body, they do not know how to attack such a problem—if indeed they *ever really* knew. Perhaps if they were told that each C-shaped mass is a rigid body describing plane motion, they would know where to look for help in a book. I have used this problem twice with graduate students and once with seniors, and the best performance was to have only 30% set up correct dynamic equations.

The most common error is to set up a moment equation about one of the two pivot points including centrifugal force as a real force but ignoring the tangential component of inertia force and the inertia couple that would need to be included for a correct application of D'Alembert's principle. The reason for wanting to take moments about the pivot point may be to eliminate from this one equation two unknown forces, or perhaps it is because the presence of a

pivot suggests moments in some irresistible way. Maybe our students have too much practice in writing moment equations in static cases before facing a situation in dynamics. I suspect that the usual course in dynamics does not include enough problems where the student has to think through for himself questions of choice of axes.

The basic trouble here, as I see it, is that the students are unable, in the words of the report, "to abstract a simplified model" from this situation. They are unable to see by themselves that each of the weights is a rigid body describing plane motion in a circle. If they saw this and then really understood how to apply the laws of motion in the case of plane motion, they would have no difficulty. There is a big difference in a student's being able to work a problem when he knows the type into which it falls and his being able a year or so afterward to decide for himself its type and then take correct action. My opinion is that there are too many possible types of problems to be learned and that successful teaching must be focused on the minimum number of principles that have the most general usefulness.

My overall conclusion is that engineering mechanics as often taught at present is too highly subdivided into special cases and special methods. We should face the fact that only the really fundamental principles have permanent and universal value. In mechanics these are chiefly Newton's Laws and supporting geometric and kinematic relationships. These are the things to concentrate on and they are truly mastered by the student only as he has experience in applying them himself. The principal job of the teacher as I see it is to set up challenging problems that give the student experience in abstracting the simplified model and force him to reason correctly from the fundamental principles. Learning shortcuts and special methods is largely a waste of valuable time. I will believe that we are headed in the right direction when new mechanics texts start getting thinner rather than thicker, as has been the trend for many years. If this happens it will mean to me that teachers have begun to think really effectively about how *little* the student needs to *understand* rather than about how much he can be exposed to without pain.

ENGINEERING SHORT COURSES AT TEXAS A. & M.

The Engineering Extension Service of Texas A. & M. College is offering a group of short courses this spring and summer on the campus. These courses are forty hour, five day courses in supervision: General Course in Supervision, April 20–30; Management Course in Supervision, May 11–15; and Municipal Supervisors' Course, June 8–12. Information on these courses can be obtained from L. K. Jonas, Chief, Supervisory Development Division, Engineering Extension Service, Texas A. & M. College System, Box 236 F. E., College Station, Texas.

DISCUSSION OF THE FOLLOW-UP COMMITTEE REPORT ON PROPERTIES OF ENGINEERING MATERIALS

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Presented at the June 1958 Annual Meeting of ASEE, at the University of California, Berkeley. Recommended for publication by the Mechanics Division.

A rapid change is taking place in the teaching of engineering materials. The transition from the former empirical presentation of instruction on engineering materials to a more theoretical approach to the nature and behavior of materials was perhaps long overdue. But it is nevertheless timely to reflect on various aspects of this change; to reconsider the advantages of this transition; and to review its possible deficiencies.

It is not my purpose to present a closed solution to the problem of teaching engineering materials. I sincerely believe that no single closed solution exists. My intent is to stimulate a discussion on this subject with the viewpoint of exchanging ideas. I will attempt to do this by illustrating several problems.

There are at least three different methods that can be used in the presentation of a course on materials.

First: Motivation Method. Many engineering educators believe that engineering motivation is the most significant factor in successful engineering instruction. In its extreme form, instruction from the viewpoint of engineering motivation would consist of presentation of an engineering application problem followed by a discussion of the factors involved and leading eventually to a discussion of the engineering science in support of the final decision or selection. This I believe is a wasteful procedure. We do not employ this technique in dynamics, fluid mechanics, thermodynamics, or the other disciplines of engineering. Rather, for efficiency, we first attempt to give the students the analytical and philosophical tools which may be applied in an area of engineering; following this we generally illustrate the utility of the tools in special types of applications.

Second: Phenomenological Introduction. On some occasions the students' interest might be stimulated by introducing a subject by way of a phenomenological description. Such a phenomenon might be the yield point observed in mild steels. The descriptive introduction might then be followed by a theoretical discussion of the origin of this phenomenon. But in the case of the example selected, the theoretical discussion would have to be prefaced by a rather lengthy description of dislocation theory plus knowledge of interstitial diffusion of N and C in steels. Frequently this method is cumbersome and unwieldy. It does not easily lead to a systematic sequence of instruction for understanding the nature of properties of materials.

Third: Theoretical Approach. The theoretical approach has recently been given much verbal support. Perhaps the emphasis on this approach in large measure stemmed from the fact that this method was so successful in the development of semi-conductors.

In general it is based on the now well-recognized fact that the properties of materials can be deduced from an intimate knowledge of their structure. Therefore the instruction starts with the structure of the nucleus, the structure of the atom, the four types of bonds, the kinetic theory of gases, the structures of solids and the role of bonding and imperfections in determining their physical, chemical and mechanical properties, the structure and bonding in liquids, followed by high polymer structures and properties and the structure and properties of cement paste and organic fibers.

This approach might be illustrated by the example of dislocation theory. Applying the theory of elasticity we calculate the yield strength of an ideal crystal to equal the shear modulus of elasticity divided by 2π. Real crystals have a strength of 10^{-4} of this value. Therefore real crystals contain imperfections that permit easy glide. The defects we can visualize are point, surface and line imperfections in the lattice. Point defects in the form of vacancies and interstitials cannot account for glide on a slip plane in a slip direction. Neither can surface defects. Therefore the defect must be a line imperfection. We then construct a model of line defects or dislocations and from this model we deduce the mechanical behavior of crystalline materials.

The key to the theoretical approach consists in deducing a good model or mental image of the atomistic structure of materials. Once a good model has been obtained, a host of properties can be deduced from the model; equally the model can be used to predict as yet unknown properties. This unified picture of the model and the predictions that it facilitates has prompted the wide-spread acceptance of this philosophical approach to engineering science instruction in general.

Although the virtues of the theoretical method of instruction are obvious, the question arises as to whether it has any weaknesses. The answer is yes. First the model is a mental approximation to the exact facts. It aids in correlating a wide variety of phenomena and in predicting new phenomena. But the precision of the deductions and predictions are limited to the accuracy with which the model was formulated. Therefore the model must always be checked against actual experimental results. The model itself is not inviolate. Second, models for many phenomena are not yet well established. For example no completely satisfactory model is presently available for fatigue. Yet knowledge of the behavior of materials under repeated stresses is very important to engineers. This suggests that the theoretical approach must yet be supplemented with phenomenological descriptive subject matter of engineering importance wherever the theory is inadequately developed to account for all of the facts.

I would now like to consider the background a student should have to appreciate a modern beginning course in materials. It can be argued, with modest success, that instruction can be attuned to any level. This argument might be valid if the objective is merely instruction of the student. But if the objective is education in the basic science of materials, a certain maturity and mental attitude must be required of the student. Many factors demand this. First, the analysis of materials is not a single discipline such as is encountered in statics and dynamics. Here a single principle, Newton's Second Law, is applied and reapplied time and again in all of its equivalent aspects. In contrast a basic introduction to engineering materials demands the synthesis of a large number of varied disciplines. If reason-

able progress is to be made, the student must have some background in mechanics, electricity and magnetism, heat, light, chemistry, and some mathematics. Part of the instruction on materials will be extrapolations of his previous knowledge, but others will have a startling new philosophical aspect for him. For example, the student will find that not all solids have their stoichiometric chemical compositions; that some of the lattice sites are occupied by vacancies; he will write equilibrium constants for reactions between solute atoms and vacancies; he will learn that the mechanical properties of liquids are best described in terms of vacancies; he will learn that some semiconductors conduct by transfer of electron holes. In general these concepts are not beyond the grasp of the sophomore student if properly presented. On the other hand they do demand that the student acquire a philosophical viewpoint; they demand that he recognize that the key to his understanding does not end with the facts; that the important factor is his mental image of the atomistic nature of the origin of the facts.

Now let us consider briefly the minimum time that might be required to present a substantial beginning course on the theory of the behavior of materials. I have already mentioned that a number of different disciplines must be applied to achieve an understanding of the nature of the properties of materials. The synthesis of these various disciplines requires careful development. Furthermore it has been my experience that each lecture on materials introduces the student to several new concepts and a rather extensive new vocabulary. It takes time to assimilate this new language and digest accurately the new ideas. It is my personal opinion that the usual 3 units for a general introductory theoretical course on materials is inadequate.

At least two methods of organizing the sequence of instruction are available in a theoretical course on materials. In one, which I will call the property sequence, each type of property is discussed in turn. For example, lectures could be devoted to specific heats or coefficient of expansion, diffusion, plastic deformation, etc. The lectures on deformation might cover the viscosity of gases, deformation characteristics of crystalline solids, the viscosity of liquids and the anelasticity of cross-linked high polymers. This method has the advantage of emphasizing the properties themselves. But it frequently has the disadvantage of relegating the all-important factor of structure to a position of secondary importance.

An alternate sequence is based on the structure of materials. In this case materials are classified in terms of their atomic and molecular structures. An example of such a classification might be gases, crystalline solids, liquids, and high ploymers, with further amplification of the types of chemical bonds that are operative. Then the properties of each class of materials might be described in terms of the common structural features of that class and the types of chemical bonds they exhibit.

The formulation of a beginning theoretical course on properties of materials introduces a number of problems. I have mentioned only a few of them here in an effort to stimulate discussion. Many more exist. I hope discussion will bring them to light.

INTRODUCTION TO ENGINEERING MATERIALS AT THE UNDERCLASS LEVEL

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University of Michigan
Ann Arbor, Michigan

This article describes the teaching of engineering materials at an underclass level. This introduction to materials is accomplished through the use of the principles which govern their properties. The procedure is outlined and includes (1) the structure of the materials from atomic to macroscopic, and (2) the effects of service environments upon the materials. The results have been encouraging and warrant a continuation of the approach even with the possibility of some selected upgrading. When the background and the ability of the student are normal, the class level of the student made surprisingly little difference on his performance in the course. There is a slight advantage in teaching at the sophomore level because the students perform more uniformly. The advantage of postponing such an introductory course beyond the fourth or fifth semester is questioned unless additional physical chemistry is present within the curriculum. Subsequent, more advanced courses in materials will be desirable for some curricula.

This paper summarizes an experiment in which engineering materials were taught as an introductory engineering science rather than as a descriptive subject. This introductory course is taught to students of all conventional engineering curricula. Several of the curricula have subsequent courses in materials which are more specialized in nature. The decision for this teaching modification originated during the 1955–56 school year on the basis of two main considerations.

First, the number of materials which are available to the engineer has become so great that it is impossible to cover individually the properties of all categories of materials in any reasonable time. In addition, many materials may have their properties altered by appropriate processing so that the list of data available to the prospective engineer is compounded. Also, there is every indication that the list of available materials will continue to grow almost indefinitely.

Second, the physical and engineering scientists have placed at the instructor's disposal many correlating principles which remove the necessity for individual attention to each material. The teaching of the principles which govern the properties of the materials gives the student a basis for understanding those many materials which are not encountered directly in classroom assignments. In effect, this permits the student to expand the scope of materials which he can consider in his design. Of prime importance, it should give him the potentiality to consider new materials as they are developed.

Course Outline

An attempt was made in the spring of 1956 to outline the engineering materials course on the basis of the principles which are available to the engineer for understanding materials. The proposed approach considered materials on the basis of (a) their structures, atomic to macroscopic, and (b) the environment which they encounter in service (1). It was decided to use this approach on a trial basis during the school year 1956–57. A syllabus

was prepared to give guidance to the student. The outline which was established is given below. Although both structural and environmental principles were emphasized, efforts were continually made to utilize engineering illustrations.

1. Introduction to the engineering requirements of materials.
   Engineering uses of materials,
   Engineering properties,
   Selected definitions.

2. The internal structure of engineering materials.
   a. Crystals, cubic structures; atom size, unit cells; density; Bragg's Law; crystal planes.
   b. Atomic structure; ionic, covalent, metallic, and Van der Waal bonds; effects of bonds on properties.

3. Single phase metals.
   a. Solid solution and grain structure.
      Substitutional and interstitial solid solutions; effects on electrical properties; grain structure; grain size.
   b. Deformation and mechanical properties.
      Elastic deformation; plastic deformation; recrystallization; variation of mechanical properties: (1) by cold working, (2) by solid solution, (3) by grain size.

4. Multiple phase metals.
   a. Equilibrium diagrams.
      Solubility; phase diagrams; freezing ranges; quantities of phases, lever rule; material balances; heating and cooling.
   b. Iron-carbon alloys.
      Ferrite, austenite, cementite; Fe-C diagrams; eutectoid reaction; transformation temperatures; pearlite.
   c. Effect of microstructure upon mechanical properties.
      Effect of phase quantities; effect of phase distribution, effect of phase size.
   d. Reaction rates.
      Time lag; nucleation; isothermal transformation; catalysts; martensite; tempering.
   e. Control of microstructures and mechanical properties by reaction rates.
      Isothermal transformation; quenching and tempering; maximum hardness; hardenability; age or precipitation hardening, graphitization.

5. Organic materials.
   a. Molecular structures and bond.
      Organic materials; molecular structures, and size; inter-molecular bonding.
   b. Polymerization principles.
      Addition and condensation polymerization; copolymerization, degradation.
   c. Effect of polymer structure upon "plastic" properties.
      Deformation of plastics; polymer shape; cross-linking; branching; orientation and crystallization; elastomers.
   d. Modification of "plastic" properties by non-polymeric materials.
      Activators; fillers; plasticizers; solvents; inhibitors and stabilizers; pigments and dyes.

6. Ceramic materials.
   a. Structure of ceramic minerals.
      Comparison with metals; coordination number; solid solution; silicate structures;

polymorphism; glassy structure.

b. Reactions involving ceramic minerals.
Vitrification, devitrification; dissociation; hydration.

c. Effect of structures upon properties.
Mineral stability; plasticity; friability; tensile strength; ion exchange.

7. Aggregated materials.
Particle size and packing factor; density and porosity; concrete; sintering.

8. Service behavior of engineering materials.

a. Mechanical behavior.
Fatigue; impact failure; wear and abrasion.

b. Thermal stability.
Viscous flow; creep and rupture; spalling, oxidation.

c. Chemical stability.
Solution; galvanic corrosion; corrosion protection.

d. Electrical behavior.
Conduction, insulation, dielectric strength; semiconductors; magnetic behavior.

e. Radiation behavior.
Interaction of radiation and matter; radiation damage.

Student Performance

This course in engineering materials is basically a second semester freshman or a first semester sophomore course as taught at the University of Michigan. (a) Those students who enter with a good high school chemistry background as shown by a placement test take an accelerated general college chemistry course during their first semester and normally take the course in engineering materials during their second semester. (b) Those students who take a full year of general college chemistry usually enroll in engineering materials during their third semester, or later. (c) Transfer students usually take the course during their first semester at the University, which is normally their fifth semester in college. In addition, scheduling complications make it necessary to invert the chemistry and materials courses in the schedules of some of the students in (a) above. Thus, a few students with a good background in chemistry may take the engineering materials course during their first semester. Consequently, it is relatively easy to make a direct comparison between the accomplishments of the students at the various levels of background. These results are summarized in Figures 1 and 2 with statistical significances expressed in Table 1.

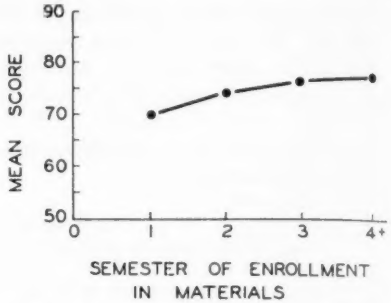

FIG. 1. Average performance vs. class level.

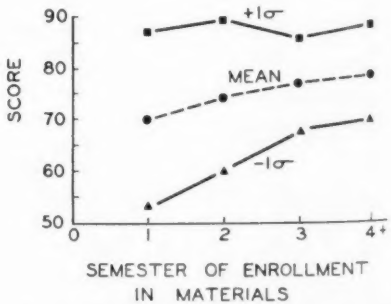

FIG. 2. Performance range ($\pm 1\sigma$) vs. class level.

TABLE 1

SIGNIFICANCES OF DIFFERENCES IN STUDENT PERFORMANCES

Comparison	Mean Scores	Statistical Probability of a Real Difference
(a) 1st semester students	70	
vs.		73 percent
3rd semester students	77	
(b) 2nd semester students	74.5	
vs.		75
3rd semester students	77	
(c) 1st semester students (who continue through the third semester)	72	
vs.		60
3rd semester students	77	

The grades averaged slightly higher for the more advanced students. Furthermore, the spread was reduced (Fig. 2). These results are to be expected, and two explanations can be suggested: (1) Additional college background gives experiences to students which can be utilized in the materials courses. (2) The few weaker students dropped out during or after their first year and as a result a third semester class naturally has a higher and more consistent performance than a first semester class.

The measure of the two influences, background and selection, upon the results of Figure 1 was possible. The average and spread of the grades for those students who took the materials course during their first semester was recalculated after eliminating the grades of the weaker students who dropped out of school before the third semester because of poor grades in other courses. Only grades of courses other than engineering materials were considered as factors in drop outs, so as to avoid any effects which could be induced by poor performance in the materials course itself.

Figure 3 replots the performance of the first and third semester students for those students who had at least three semesters of college. The difference may be attributed to the contribution of additional background in freshmen subjects. A statistical evaluation indicates that the difference has a 60 per cent probability of being real. Pedagogically there is no reason to doubt that the difference is real; in fact, if any comment were to be offered it would have to be an expression of surprise that the difference is not greater. No attempts have been made to sort out the reasons for the lack of a greater difference. However, a candid opinion would cite the fact that the structural concept of materials is generally not encountered in the freshman engineering or introductory chemistry and physics courses. As a result, this concept is new to all students whether they be freshmen or sophomores. In fact, it is new to most of the upper classmen, since the average engineering student does not study physical chemistry.

The chief difficulties encountered by a lower underclass student in the course as outlined above are the three-

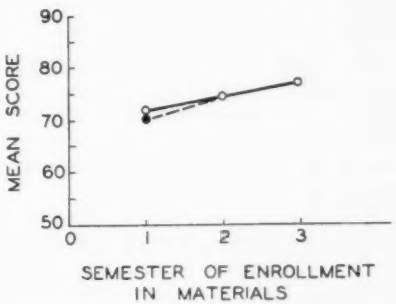

FIG. 3. Average performance vs. class level for students who complete three semesters of college.

–○– Average score for those students who complete three semesters of college and take materials in the indicated semester.

–●– Average score in materials of all students who take materials in their first semester (same as fig. 1).

dimensional applications of geometry and trigonometry in considering crystal structure. Once this was mastered, other concepts came more readily. Surprisingly little difficulty was encountered in the introductory consideration of polymeric materials even in the absence of an organic chemistry background. The students showed an ability to handle the electrical concepts of materials better than had been anticipated in the original outline. In fact, there are a number of parts of the original outline which could be upgraded with little difficulty even though the course is handled at an underclass level.

Evaluation

As shown in Figure 1, there is a slight advantage in postponing a course in principles of materials of engineering until the sophomore year, although it is less than would have been anticipated. The advantage is mainly that the homogenization of the students' performance eases teaching (Fig. 2).

For the bulk of the engineering students, there seems to be little advantage in postponing the materials course to the upper class levels. The average engineering student receives only general college chemistry and little or no structure of solids in his physics. Thus, further postponement does not contribute significantly to the background for a materials course. The chemical, metallurgical and ceramic engineering curricula could be an exception to this statement. These three curricula do include additional physical chemistry.

Naturally an instructor who is interested in materials would like to have all the students possess an extended background in both physics and chemistry prior to entering the course in materials. With a physical chemistry background, less time would have to be spent on introductory details and more time could be spent on refinements or applications of the principles to real materials. However, this personal desire of the staff member will not be generally met until there is a major increase in the science content of the engineering curricula.

An introductory course such as this cannot meet all of the needs of materials for any engineering curriculum. Each curriculum will require subsequent, more specific courses in which greater attention is paid to the properties of individual materials and to applications of materials in engineering designs.

References

1. Although the above approach was formed independently, it is interesting to note that it is similar to that discussed later by the ASEE Follow-up Committee for Evaluation of Engineering Education. (*The Engineering Sciences*, ASEE, Berkeley Meeting, 1958.)

AERONAUTICAL DIVISION—ARS JOINT SESSION

The first joint session of the Aeronautical Division and the American Rocket Society will take place Thursday afternoon June 11, 1959 in the El Cortez Hotel, San Diego, California. A panel presentation on "Combustion Topics in Curricula" is scheduled. Panel members will be Ali Bulent Cambel, Northwestern University; Robert S. Levine, Rocketdyne Division of North American Aviation; K. Scheller, Aeronautical Research Laboratory of W.A.D.C.; and A. L. Cronk, Texas A and M. The program is being arranged by Carl A. Anderson, Air Force Institute of Technology and A. L. Cronk, Texas A and M.

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Dr. James H. Pitman

A CHAIRMAN'S LETTER TO HIS DEPARTMENT

On October 1, 1958, death came to Dr. James H. Pitman, Chairman of the English Department and the Humanities Division of Newark College of Engineering. Dr. Pitman had been a member of ASEE since 1945 and had made a valuable contribution to the Society's work in the interests of engineering education. He was a past chairman of the English Division, had served on numerous committees, and was a member of the Council 1956–1958. He was active in English Division affairs and had a part in the establishment of the Humanistic-Social Survey Research Project.

James H. Pitman was born in Newark, took his A.B. from Rutgers and his Ph.D. from Yale in 1922. He had been at Newark since 1940. He is survived by his daughter, Mrs. Charles Bogert, and two sons, David H. and Robert L. Pitman. Dr. Pitman was 62 years old.

The following is taken from a letter written by Dr. Pitman to his department in September of 1955. The ideas expressed here may help teachers of both the humanities and engineering to better understand the work of the humanities teacher. The text was supplied by Professor W. H. Grater of Newark College of Engineering and is reprinted with the permission of Dr. Pitman's daughter.

To the English Department:

Each year, as I approach a new first semester, I become very conscious of the complicated activities we face, and I try once more to coordinate them in my own mind. This year certain discussions at the ASEE meetings have made me reexamine my ideas, and at this moment I feel that, more distinctly than ever before, I have clarified my concept of what our department should and can be.

Any English Department on the undergraduate level has two closely related functions. It must develop its students' ability to express themselves orally and in writing, but—and this is perhaps the more important—it must introduce them to the world of ideas. In some colleges these functions are separated—sometimes even into three parts: speech, composition, and literature, but in most places they are the responsibility of one department.

I feel that this latter practice is the best. Any attempt to separate substance from form—what we have to say from how we say it—is unsound. Just as having something to teach should come before one worries about techniques of teaching, so being someone should come before one worries how one should express oneself. Having something to say comes before one worries about how to say it. Facts and ideas without techniques for expressing them may be like the Cheshire cat without his grin, but techniques without something to express are certainly like a grin without a cat. The all-important function of any English Department, as I see it, is to develop the mind and character of our students. Techniques of expression, important as they are, should be a by-product of that function.

An English Department in any way connected with an engineering college is under special pressures. One is the pressure of time, but the other, though

more subtle, is even more important. Engineers and men in industry pay considerable sincere lip service to general culture, but in a showdown on the English curriculum I find that most of them consider it mainly or even solely a means of teaching the writing of factual material (more often called "technical writing" or "report writing") and the techniques of "public speaking."

Under these pressures various things occur. Where the engineering school is a small part of the whole institution, the English Department, if strong enough, may resist all attempts to adapt its subject matter and methods to the limited time and the special needs of engineering students. The result is usually a feud between the two factions, neither of which has all the right on its side. But in a strictly engineering college the English Department may capitulate to the "communicationists" and give the engineers what the engineers think they want, so that the great general function of an English Department almost ceases to operate. Throughout the country one finds all sorts of gradations between these two extremes, the determining factors being a blend between the attitude of the administration and the personalities of members of the engineering faculty and the English Department.

* * *

There is one great difference between our department and a "standard" English Department. In many liberal-arts colleges the prime function of the department is to teach potential English majors; there is a specific body of subject matter which must be covered; the history of English literature, the principal and some of the minor authors and works of each period, and the generally accepted critical judgments. That is just what you and I needed in college.

But at NCE our function is different. We have no English majors, we have little time for the history of literature, and the "right" critical judgments, so important to us, are of small interest to the ordinary educated man. We are not teaching literature, but are rather trying to use literature to enlarge the mind and develop the character of our students. What we teach is of little importance, so long as it is worthy material; the results we get in terms of developing personality are what count. But by their very nature, our results are almost impossible to measure, at least while we have our students with us. If we do our work well, only their whole lives will show whether we have succeeded. And so—as in most good works—we must proceed by faith that men are sure to benefit by contact with great ideas and great expression.

It is with this thought in mind that I try to leave you as free as possible in your manner of handling our work. I have chosen you quite as much for what you are as for what you know. And so I really want you to teach yourself, and to do it in your own best way. We must, of course, use the same textbooks and have our students do more or less the same amount of work, but within that frame I want to leave you free. So long as you look with affection at your students—as men of good will always look at young growing things—you will teach them well.

Every semester brings its share of little problems and annoyances, but these can all be solved or eliminated if we agree on our main tenet: that we are not merely imparting information but are helping our students to grow in knowledge and character to the limit of their ability.

Nothing really matters but that.

JAMES H. PITMAN, *Chairman*

A S E E

ENGINEERING EDUCATION EXCHANGE MISSION

TO THE

SOVIET UNION

NOVEMBER, 1958

FINAL REPORT

MEMBERS OF THE DELEGATION

1. Frederick C. Lindvall, *Chairman*
2. Newman A. Hall, *Secretary*
3. William T. Alexander
4. William L. Everitt
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6. Albert G. Guy
7. Ralph A. Morgen
8. Leon Trilling

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SUMMARY OF OBSERVATIONS

In the UUSR learning and accomplishment are respected and honored in a way not even approached in the USA.

Differences in economic, social and political environment make difficult a meaningful comparison of engineering education in the USSR and the USA.

The objective of higher education in the USSR is to prepare individuals for the service of the State.

The motivation of the student for superior accomplishment is the most outstanding feature of engineering education in the USSR. This motivation is based on prestige, privilege, financial reward, and obligation to serve the State.

Complete financial support is available to qualified students where there is need. This includes approximately 85% of the engineering students. Support is withdrawn in case of failure and increased for superior performance.

A secondary school education closely coordinated with engineering curricula provides a superior training in science, mathematics, and languages.

An average of only about one in four who seek entrance gain admission to engineering institutions (VTUZ's). Application may be made to only one institution, and in only one of its specialties, in any given year. Admission standards vary as a result of the competition because the best talent generally applies to a limited number of superior institutions where the most distinguished faculties are located and where special provision is made for the development of the student's talents.

Attrition is low due to the high selectivity and motivation. Approximately 85% of those admitted complete the basic engineering program.

Detailed planning for all educational institutions of higher learning is centralized in the Ministry of Higher Education. However, this centralized administration still provides for experimentation and development of the educational program.

In spite of centralized planning and uniform requirements, considerable differences in the quality of the educational programs in engineering exist throughout the USSR. The range in quality is comparable to that found in the United States.

Engineering education is carried on by a variety of higher technical educational institutions, rarely including universities, but including many with restricted objectives as well as some limited to evening and extensive correspondence programs.

The plan of instruction seems to be similar to the European system. Lectures are by mature staff members, but assistants are responsible for the recitations and laboratory work.

The prestige of the professor is higher than that of chief engineers and executives in industry and his salary is comparable to theirs.

The rank of professor is awarded by the State to individuals who have been selected by competition for an available position and who have attained the doctorate degree or its equivalent in industrial experience. The title is permanent, but the individuals must stand a competition for the position every five years.

The rapid expansion of educational programs and the demands of the economy have produced a shortage of academic staffs at the mature level.

A substantial obligation of the academic staff is the development of teaching aids and laboratories. This results in good laboratories and outstanding demonstration equipment.

The buildings for the engineering educational institutions in the USSR are crowded. However, equipment and instrumentation in the laboratories are adequate.

A high degree of specialization in engineering is evidenced by the existence of some 200 approved curricula.

Receipt of a diploma in engineering in the USSR corresponds roughly in academic content to the awarding of a bachelor's degree in the USA. In certain respects this diploma approaches the level of the master's degree in the USA. The USSR curricula contain much industrial training which is required for the graduate to immediately function as a professional engineer, and which in the USA is expected to be obtained during his first few years of employment.

The graduate engineer is expected to be a skilled draftsman and a competent craftsman in the trades pertaining to his specialty.

The need for graduate education is confined to those who plan to work for a research or teaching institution; the diploma is all that is expected for employment in industry. The first graduate degree, Kandidat of Technical Science, approaches the level of the doctor's degree in the USA. The degree of Doctor of Technical Sciences represents a higher level of achievement.

According to the best information obtainable for engineering, in 1958 approximately 80,000 diplomas, 1,000 kandidats, and 120 doctorates were awarded in the USSR. During the next seven year period it is planned to increase the enrollment in engineering by 90% over the average of the last seven years.

Senior members of the teaching staff have light teaching loads because research is expected to occupy about 50% of each professor's activities. Engineers as well as scientists participate actively in the work of research institutes under the Academy of Science and the industrial ministries.

Engineers are well represented in the membership of the Academy of Science.

Much of the engineering research activities is in the research institutes as well as in the engineering teaching institutions (VTUZ's). Work towards graduate degrees is carried on at these institutes and many professors are employed by them.

I. INTRODUCTION

It has been said that there are no experts on Soviet Russia; there are only degrees of ignorance. To dispel some of the uncertainties about the details of engineering education in the USSR, an Exchange Mission was organized by the American Society for Engineering Education at the request of the Department of State to make a specific study of this branch of education at as many representative schools as possible in the Soviet Union.

During the winter of 1958 the Lacey-Zarubin agreement was concluded for the exchange of cultural, scientific and technical missions between the United States and the USSR. Later that spring the State Department invited ASEE to organize an exchange on engineering education. The ASEE General Council authorized an Ad Hoc Planning Committee consisting of W. L. Everitt, N. A. Hall and F. C. Lindvall to make detailed arrangements. In the name of the Society a proposal was submitted to the National Science Foun-

dation for a grant to defray the expenses of the delegation to and within the Soviet Union, as well as some expenses incidental to the visit of the Russian Exchange group to the United States. This proposal was approved and funds were made available in November, 1958.

The American delegation was selected by ASEE with three objectives: 1) official representation of the ASEE and the Engineers' Council for Professional Development; 2) broad representation of engineering schools and technical areas; 3) initial familiarity with the Russian language and educational system. The chairman of the delegation was Frederick C. Lindvall, chairman of the Division of Engineering at the California Institute of Technology; the secretary was Newman A. Hall, chairman of the Department of Mechanical Engineering at Yale University. Other members were William T. Alexander, Dean of Engineering at Northeastern University and president of ASEE; William L. Everitt, Dean of Engineering at the University of Illinois and president of ECPD; Ralph E. Fadum, Head of the Department of Civil Engineering of North Carolina State College; Albert G. Guy, Professor of Metallurgy at Purdue University; Ralph A. Morgen, Professor of Chemical Engineering at Purdue University and Director of the Purdue Research Foundation; and Leon Trilling, Associate Professor of Aeronautical Engineering at the Massachusetts Institute of Technology.

The itinerary, which was the result of negotiations between the delegation and the Soviet Ministry of Higher Education, included a number of leading schools in Moscow and Leningrad, some representative schools in a large provincial city (Kuibyshev) and some recently founded schools in a young, developing Soviet Republic (the Kirgiz SSR), as well as a number of Research Institutes and Administrative Divisions of the Ministry of Higher Education. The itinerary was selected in an attempt to gain a balanced view of the various aspects of Soviet engineering education within the limitations imposed on any foreign group which travels in the USSR. The detailed itinerary of the delegation is given in Appendix A.

The purpose of the mission was to obtain factual information about the scope and method of operation of Soviet engineering education in an attempt to determine how effective it is in filling the needs of the Soviet economy, and to learn whether any new techniques were used which might be applicable to our own educational system.

It became quickly evident, however, that Soviet education must be evaluated within the Soviet frame of values and, though it appears suited to their society, its main features are not directly comparable to ours. The present report, therefore, mainly presents an analysis of the Soviet system as the delegation found it, and some general comments on the implications it may have for the United States.

The delegation on behalf of ASEE acknowledges the assistance of the National Science Foundation, which financed the mission. During advance preparations invaluable assistance was provided by Nicholas DeWitt of the Harvard Russian Research Center and by Alexander Korol of the Massachusetts Institute of Technology Center for International Studies. During the tour of the USSR the Ministry of Higher Education served as an efficient host. Its representative, G. G. Mukhin, as well as three interpreters provided by the Ministry, made every effort to accommodate our requests and to make our visit successful and comfortable.

II. FRAME OF REFERENCE

In order to understand the engineering educational system in the USSR, some consideration must be given to the political and social framework within which this system operates. The whole economy of the USSR is integrated into a broad plan devised by the state planning commission (GOSPLAN). The formulation of the portion of the master plan related to engineering education is the responsibility of the Ministry of Higher Education. A long-range plan, covering a period normally of five years, is formulated first. Each year the master plan is modified to take into account the accomplishments of the previous year. The plan considers the needs of the whole Soviet Union in the light of the proposed expansion of industrial plant capacity and the need for personnel to provide for this expansion and for retirements, replacements, and upgrading. The master plan specifies the number who may enter the institutions of higher education, the number who may train for each field of specialization, the quota of each specific institution for each specialty and the jobs available at the time of graduation.

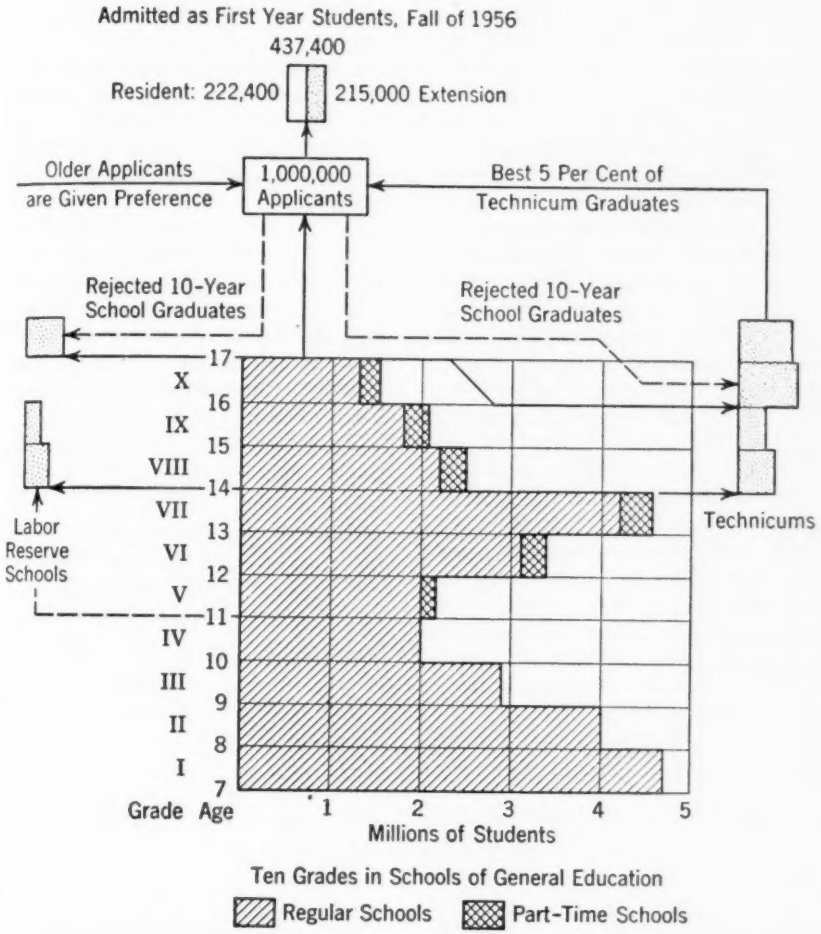
The rate of expansion of the building program is indicative of the rate of expansion of the industrial economy. During the period of the present plan, from 1959 to 1965, the contemplated increase in the total building program for the USSR as a whole will be 180%. The increase in the underdeveloped areas may even exceed this figure. For example, in the Kirgiz Republic the increase is expected to be 230% with respect to the previous five year plan. This includes an increase of 270% in housing, 310% in public services and 240% in facilities relating to health, education and culture.

In conformity with this increase in industrial development, the plan as now formulated contemplates 350,000 graduates in all professional fields (engineering, science, medicine, language, etc.) a year by 1965. This represents an increase of 40% over the average of the past five years, but in engineering the proposed increase will be 90%.

Nowhere are the engineer and scientist held in higher regard than in the USSR: they are among the aristocracy of Soviet society. Engineering students and practicing engineers are exempt from military service. An engineering education opens the door to positions of high rank. On the other hand, to achieve such positions without some type of diploma would appear virtually impossible. In general the limit of achievement of the non-graduate in the future in an industrial enterprise is the position of foreman, while this is considered to be the starting position for a graduate. There is, therefore, strong motivation and social pressure to aspire to a career in engineering.

A motivation factor not to be underestimated is the strong devotion to a system that greatly encourages education. Such a system, offering unique advantages to the educated, instills a strong desire for education in the youth of both sexes. Currently about one-third of the total enrollment in the schools of engineering technology is comprised of girls. Competition for admission is keen and a seriousness of purpose pervades the classroom and laboratory.

In the USSR, school begins at the age of seven. Grades one through seven comprise the elementary school, grades eight through ten the middle school. Higher education is offered both at technical institutions and uni-



Progression to Higher Education in the Soviet Union. Reproduced, with permission, from Alexander G. Korol's *Soviet Education for Science and Technology*, published jointly by The Technology Press of the Massachusetts Institute of Technology and John Wiley & Sons, Inc.

versities. A student entering a university or a technical institution does so after the ten year school and his program of study lasts from five to six years.

With rare exceptions, engineering education is offered only at the VTUZ's (Higher Technical Educational Institutions). Such institutions have the right to award degrees only in the technical sciences. The universities are concerned with mathematics, basic sciences, language, etc. In general the function of the university is to prepare students to enter teaching; whereas the function of the VTUZ is to prepare students for careers in industry and research establishments.

In addition to the universities and the VTUZ's, there is an intermediate program of higher education similar

to that offered by our "technical institutes." Schools offering such programs are called "technicums." The student enters a technicum after the seven year school or after the ten year school. In the first case, the curriculum extends over a four year period, in the latter case, 2½ years.

The entire Soviet educational system is standardized. Curricula pertaining to all levels of education are uniform throughout the USSR. The time schedule is set for each of the various courses that comprise the curricula and the detail is worked out even to the extent of specifying the number of hours of lecture, laboratory and practice periods.

Currently consideration is being given to a drastic overhauling of the higher educational system, particularly that related to engineering. It is reported that this reorganization will be gradual. The new plans will provide for more practical experience during the course of study, in order to make the graduate even more immediately useful to industry upon graduation. In addition to these educational considerations, the changes are being prompted by a fear that a gap is developing between the working class and the intelligentsia. Every effort is reportedly being made to "annihilate any difference between these classes."

Within the framework of a growing "planned" society, the specific objectives of Soviet higher education have been summed up as: * (1) the ideological-political education of the students and instructors in the foundation of the teachings of Marx, Engels, Lenin, Stalin; (2) the preparation of cultured specialists of high qualification for all branches of the people's economy and culture; (3) the conducting of scientific research to assist in the solution of the most important problems of socialist construction; and (4) the popularization of scientific and technical knowledge and the newest achievements of science and technology among the broad masses of the population.

III. THE ADMINISTRATION OF THE SOVIET HIGHER EDUCATION SYSTEM

The administration of the Soviet higher education system is thoroughly centralized and is entrusted to a number of government agencies, the most important by far being the Ministry of Higher Education of the USSR (Appendix B). In addition, a number of ministries run their own special engineering schools (communications, defense, transport, agriculture, etc.) and other schools (medicine, teaching, fine arts, etc.). Research institutes, where much graduate training goes on, are also separately administered. A quasi-independent agency, the Higher Attestation Commission (VAK), has the responsibility of certifying advanced degrees and professorial qualifications for all institutions.

The Soviet higher education system consists of approximately 750 institutions located in some 260 cities and towns. The total enrollment in 1958 was roughly 2,100,000, of whom, 1,200,000 were daytime resident students and 900,000 were evening and extension students. Of these, 400,000

* E. N. Medynski, *Narodnoye Obrazovaniye y SSSR* (Public Education in the USSR). Moscow. 1947, p. 166. RSFSR Academy of Pedagogical Sciences, 1952. See also *Vysshaia Shkola* (The Higher School: Basic regulations, decrees, and directives), L. I. Karpov and V.A. Severtsev, eds., Moskua, 1957, p. 32.

day resident (33%) and 180,000 evening and extension students (20%) were in various fields of engineering. In 1957 240,000 students were graduated, including 80,000 engineers, of whom 66,000 were from day courses and 14,000 from evening and extension courses. Half of the students (30% in engineering) are girls. For 1958, the graduates were 290,000 total and 93,000 engineers.

From these overall figures, the scale of the Soviet effort is apparent. Two other features are significant: the relatively large proportion graduating in engineering (one-third as compared to 8% in the United States in 1958) and the effort lavished on evening and extension programs.

Ministry of Higher Education

Of the 186 educational institutions primarily concerned with engineering training, 128 are directly administered by the Soviet Ministry of Higher Education, 28 by the nominally separate Ukrainian Ministry of Higher Education and the remainder by other ministries. The Soviet Ministry is responsible for the general planning of the higher education system, the opening of new schools, and the consolidation of some of the older ones. In cooperation with the State Planning Commission (GOSPLAN), it is responsible for the planning of enrollment. The five or seven year plan, which is broken into detail and re-examined each year, is quite complete and specifies the enrollment in each department of each school.

The Ministry also closely supervises the contents of the curriculum of each specialty. Curricula are essentially uniform across the country; content is specified and only minor deviations may be permitted. Some 15 leading schools (Appendix F) may make major curriculum changes on an experimental basis with concurrence of the Ministry. The writing, certification, publication and royalty rates of textbooks and other teaching aids (films, visual aids, records, special booklets for extension course students, etc.) are likewise under the direct control of the Ministry of Higher Education.

The planning, training and placement of adequate numbers of faculty members and the application of sufficient pressure to raise the standards of faculties of all schools also fall within the province of this Ministry.

One of the Ministry's functions is accreditation and inspection. This involves the inspection of fiscal activities of each school or institute, the examination of administrative procedures at each school and the evaluation of educational activities. Except for the central audit of the expenditures of the individual schools, many of the evaluation procedures are similar to those which form a part of an ECPD inspection of curricula in the United States. Of course, in the USSR certain administrative procedures are stated by general rule rather than individual school choice, because the Ministry is the body to whom these schools are responsible. Although in some instances the school is operated by another Ministry, as, for example, the Ministry of Transport, the Ministry of Higher Education still has certain responsibilities for academic affairs and the same administrative rules concerning faculty appointments, promotions, salary, etc. apply.

In undertaking the evaluation of educational activities (which occurs every four or five years) the Ministry prepares an individual questionnaire for each school, varied to fit local situations. A team of professors and representatives from industry, selected by the Ministry, visits the school to examine the quality of instruction,

conformity to school objectives, admission procedures, quality of student work and diploma projects. The purpose of this examination is to check the quality and offer constructive criticism for modification and improvement. The committee making the visit discusses its conclusions and recommendations with the Academic Council of the Institute. The Council has an opportunity to review the findings of the inspection committee and to discuss thoroughly areas of disagreement. It may accept the recommendations of the visiting committee and proceed with their implementation. If it rejects any of the recommendations, the Ministry of Higher Education may seek additional advice on the points at issue and order changes at the school as seem appropriate. Unusual situations may call for intermediate checks varying in degrees of thoroughness. Thus in many respects the inspection procedure quite closely parallels our ECPD accreditation inspection, with two major differences: (1) the Ministry of Higher Education inspection is mandatory; the ECPD inspection is only upon invitation of the school; (2) if the recommendations of the inspection group are approved on review by the Ministry of Higher Education, the school is directed to comply. Findings by ECPD with reference to an accreditation inspection are transmitted to an institution for its information and voluntary action.

Research Institutes

A second factor in the administrative picture is the position given to research institutes because of the close relation between research and engineering education and because of the role which these institutes play in graduate training and preparation of the teaching staff. A relatively small proportion of the Soviet research program is carried out at institutions of higher learning. The major portion of the research load is carried by two types of institutes devoted exclusively to research.

The more basic research programs are sponsored, planned and carried out under the supervision and direct guidance of the Academy of Sciences of the USSR, which is not only an honorary society of the 165 leading engineers, scientists and humanists of the country, but also an active government agency entrusted with the responsibility of planning and conducting research on problems of importance to the further development of the State. It is responsible directly to the Council of Ministers.

The Academy consists of eight Departments (Mathematics-Physics; Geography-Geology; Chemistry; Biology; Technical Sciences; History; Economics-Philosophy-Law; Literature-Language) but Mathematics-Physics, Chemistry and Technical Sciences make up two-thirds of the membership. The operating agencies of the Academy are 143 research institutes (92 in natural sciences and engineering) concerned with the development of new knowledge and the training of graduate students.

In general these research institutes are allied with a scientific discipline (mathematics, soil mechanics, physical chemistry, etc.) rather than with one type of industrial or economic activity.

In addition to the Soviet Academy, there also exist academies of science in most of the Soviet Republics whose general program is similar to that of the Soviet Academy, but whose scope of activities and level of work depend on the maturity of the Republic concerned. There are also a number of academies responsible for work in certain special fields (Academies of

Medical Sciences, Agricultural Sciences, Architecture and Construction, etc.) which sponsor research in those fields.

These also exists a different class of research institutes which are more directly related to development work and are therefore responsible to specific agencies of the Government. Before the recent decentralization policy, these were responsible to the appropriate ministries. Wherever ministries were preserved, they kept their research institutes (for example, Defense, Aviation, Communications, Transport). Other institutes whose work is considered of national significance (Heavy Machinery Research Institute, Turbine Research Institute, etc.) are now responsible to GOSPLAN and essentially continue as before. The smaller institutes (Food Industry, Textiles, etc.) are now responsible to the local economic councils of their respective areas.

The second type of institutes also participates in the training of graduate students; a large part of the work done there is essentially the type of development work which is the predominant program at industrial laboratories in the United States.

While both types of research institutes are administratively separate from teaching institutes (VTUZ's), they affect engineering education not only through their role in training staff but also because many engineering professors hold part-time appointments on their research staffs and use these as a channel of communication between industrial research and education. Furthermore, an appreciable amount of teaching, especially of the more specialized technical subjects, is done by full-time research institute staff members. On occasion, especially in the larger towns, some of the brighter students do their laboratory work in the institutes.

Higher Attestation Commission (VAK)

The third major component of the administration of the higher education system is the Higher Attestation Commission (VAK). VAK consists of 78 senior professors appointed for two year terms by the Council of Ministers of the USSR; members may be reappointed and the average length of tenure is six years. From among its members, the Commission selects a chairman, an academic secretary and a ten-man presidium responsible for the day to day operations and most decisions. While the Commission is independent of the Ministry of Higher Education and responsible directly to the Council of Ministers, its chairman for the past ten years has been the Minister of Higher Education.

The central administration of the Soviet Higher Education System is thus seen to be vested in three interrelated agencies: the Ministry of Higher Education, the network of research institutes and the Higher Attestation Commission. While these are administratively distinct and independent, they form an effective whole through overlap of senior personnel.

Incidentally, reliance on individuals holding several jobs for coordinating or controlling purposes is an essential element of Soviet administrative procedure. At the highest level, one observes overlap between membership in the Central Committee of the Communist Party and positions of responsibility in the government of the USSR. At the working level, the holding of multiple jobs permeates Soviet administration. In education and research, it provides ties between the research and education streams or the industrial and education streams. Lines of authority and responsibility become confused and are often quite different from the organization chart

on the wall. There is the formalism and appearance of separation of powers superimposed on the reality of a highly centralized system. Such a system overloads leaders to the point of threatening to impair their usefulness, and may blur the channels of authority for subordinates, thus increasing their reluctance to take responsibilities.

IV. ADMINISTRATION AND FACULTY OF ENGINEERING EDUCATIONAL INSTITUTIONS

The chief administrative officer of a Soviet institution of higher learning is the Director (Rector in the case of a university) who is appointed by the Ministry of Higher Education. In most cases, the Director has the rank of professor. His responsibilities include the general administration of the school, the establishment of an organization capable of fulfilling the teaching and research plans assigned by the Ministry and of graduating the assigned yearly number of specialists, and the supervision of political and cultural activities of the staff and student body. The Director usually serves from five to ten years. In most cases, the Director prefers not to serve longer than that. In the opinion of most academic people, administrative work is considered much harder than being a professor and less rewarding in the long run. Therefore, after the term, the Director prefers to go back to his job as professor, where he can teach and do research.

The Director is assisted by one Deputy in charge of research and another in charge of teaching. These are selected from among the senior staff and appointed by the Ministry; in some of the smaller schools, these two jobs are merged. There is, in addition, an administrative assistant, appointed by the Director and confirmed by the Ministry, who looks after buildings and grounds, equipment, contract negotiations, etc. Finally, there are a number of social-political organizations (student union, professional unions, Komsomol, local party unit) which watch over the political education of the students and staff, promote internal discipline, obtain help for poorer students, and organize extra-curricular activities of scientific, cultural, social and athletic character. Representatives of these organizations also sit on the admissions and placement committees of the school.

Academic Council

The academic policy is made by the Academic Council within the limits where it may be set by the school. Within the framework of the Ministry's long term plan, the Council considers detailed curricula or proposals for curriculum modifications, recommendations for major staff appointments, appointments to minor staff positions, research programs, graduate study programs, recommendations for degrees, etc. This Council consists of the Director, his deputies and assistants, the representatives of major social-political organizations, all deans and heads of chairs, all full professors, the librarian and any other senior staff members designated by the Director. It meets at least once a month under the Director's chairmanship and its decisions are final after their approval by the Director. In some larger schools such as MVTU (Bauman Institute), where the Academic Council numbers over 70 members, most decisions are taken by an Inner Council which limits its aca-

demic membership to deans of professional courses and department heads in the basic sciences, a total membership of ten or twelve.

Faculties

The students of a school are divided among a number of administrative units called faculties, which correspond to the departments or schools of American universities. For example, a typical Soviet Polytechnic Institute will have Faculties of Metallurgy, Mechanical Engineering, Electrical Machinery, Power Engineering, Radio and Electronics, Civil Engineering, etc. Each faculty is administered by a dekan (dean) who, at least in larger schools, is a full professor. The dean is appointed by the Ministry of Higher Education on the recommendation of the Director, and is usually selected from among the professors of the faculty involved. Because of the administrative load associated with the position, it is often rotated among the senior professors of the faculty, average length of appointment being around five years.

Chairs

Within each faculty are a number of chairs (kafedry) which are similar to either departments or options within departments. In the Faculty of Power Machinery at Bauman Institute, are Chairs of Hydraulic Turbines, Steam and Gas Turbines and Compressors, Refrigeration, Boiler Design, Internal Combustion Engines. A chair is administered by a full professor or by a docent (equivalent to associate professor) on an acting basis.

The chair is closely associated with a specialty; it is responsible for training engineers of that particular specialty and has a specific curriculum to administer. In that sense, the chair is the key unit of the Soviet engineering education system. Not all the courses required for a diploma in boiler design, for example, are taught by the personnel of the chair of boiler design, but the chair is responsible for the curriculum and has academic control of the students.

In addition, institute chairs (service departments) teach basic science (physics, mechanics, chemistry, mathematics), engineering skill (shop, drafting) or humanities (foreign language, Marxism-Leninism, political economy, etc.) to the entire student body and do not administer specialized curricula. Because of the service nature of the instruction provided by these chairs and because the sciences and the humanities are the major specialties in the universities, the institute chairs are often staffed either by part-time professors who do their main work elsewhere or by expert pedagogues not primarily interested in research.

In general, the Soviet engineering schools are authorized a student to teaching staff ratio of approximately 10 or 12 to 1, but only in the major centers has this been achieved because of a lack of qualified people. Within the teaching staff, only 5 to 8% are professors, 40 to 45% are docents and some 50% are teaching fellows or assistants without advanced degree. A professorship is therefore scarcer than in the United States and almost as exclusive as in Europe.

The number of teaching positions for each school is assigned according to an overall plan by the Ministry of Higher Education, but the individual school selects the people who are to fill the available positions, subject to approval by the Ministry for professors and docents.

Requirements for Teaching Positions

The formal requirements for academic positions are closely associated with academic degrees. The position

of professor requires the doctor's degree. Similarly the position of docent requires the kandidat's degree. In rare cases the requirements are waived.

A diploma is sufficient qualification for the position of assistant or instructor; most people in these grades are working for advanced degrees.

When a vacancy for an academic position occurs, it is advertised in the professional journal of the Ministry and in the daily press, and a competition among potential applicants is announced. Applicants submit to the school a detailed history, recommendations and record of publications. The names of the applicants are made public. When all applications are in, a faculty committee reviews the applications and makes recommendations to the Academic Council. The Council then votes on the applications by secret ballot; a majority of those voting (a quorum is two-thirds of the Council) is required for the selection of an applicant. The appointment of the elected applicant becomes final when confirmed by the Ministry of Higher Education.

The ways in which this formal procedure works in practice vary a good deal among institutions. The well established VTUZ's in Moscow, Leningrad and a few other centers offer prestige, working conditions and surroundings unmatched in the USSR. They may therefore be very selective. On the other hand, vacancies at newer schools in remote provincial districts draw fewer applicants. At times those schools find it difficult to find applicants who meet the requirements of the job and must temporarily elect people without the specified qualifications. When a younger man endeavors to demonstrate his academic competence between the awarding of an advanced degree and that of the corresponding academic rank, he may seek election in such a school. In this way, smaller schools are staffed at least partly with ambitious young people and the major schools have a pool of seasoned talent to draw on.

In a competition, the list of applicants is public and failure to be elected is likewise public; hence applicants will sound out the screening committee concerning their chances and withdraw voluntarily if election prospects are poor. Thus much informal off-the-record negotiation goes on before the election and the number of formal applicants may be small.

Finally, there are circumstances when extraneous considerations play a role. If a new research center is being developed in an area, outstanding specialists may flock there and enter local competitions with the understanding that they will be elected so that they can accept simultaneous appointment to the new research center. It also occurs that some technically outstanding men find it necessary to leave Moscow or Leningrad for non-technical reasons.

Term of Appointment

Appointments in the USSR are for a five year period. Every position is declared vacant every five years and a competition is announced to fill it. In most cases, the holder of the position is one of the applicants and if his performance has been satisfactory, he is usually re-elected; often nobody else even competes for the job. But this appointment procedure makes it possible to keep the academic staff alert and to eliminate quickly those who fail to readjust their teaching and research to new technological demands.

When a faculty member is over 60 years of age (55 for a woman), he or she may voluntarily retire on 40% of full salary. Retirement is not compulsory at any age and many scien-

tists and teachers remain active well past the age of 70 or even 80. They may remain on duty as long as they desire, provided that they can secure re-election to their jobs.

If a faculty member below retirement age performs unsatisfactorily, generally the Director of the VTUZ suggests to him that his re-election is unlikely; he will then often not apply for re-election and seek election elsewhere. The general impression one gets is that if a person has taught in Moscow, he has little trouble getting a position in a smaller town. The schools in the smaller towns cannot as easily afford to let a faculty member go because of the shortage of qualified personnel. This mechanism tends to concentrate the best teaching and research talent in a few major centers.

Status and Salary

The European tradition which endows professors with considerable social prestige is reinforced in the USSR by the absence of any elite-defining feature other than academic degrees. Since the motivation of Soviet society is political and ideological, the academic clan does not make policy; but because national policy stresses that development of economic well-being and power depend heavily on learning, and particularly on technical learning, the professors, especially in the natural sciences and in engineering, enjoy much prestige and receive considerable official recognition.

The base pay of a Soviet professor is 5,000 rubles per month and that of a docent is 3,500, which may be compared to 800 rubles earned by a semi-skilled worker and 1,200–1,500 rubles earned by a skilled specialist. The teaching profession stands near the top of the Soviet pay scale; relatively much higher on the pay scale than in any other nation.

Deans get 1,000 rubles above base pay; for directors, the pay depends on the size of the institution involved. Furthermore, most engineering professors hold additional jobs which increase their salary by up to 50%; these jobs may involve supervision of sponsored research within their own faculty, simultaneous appointments at other schools or research institutes, positions within the Ministry of Higher Education, VAK or the technical councils of other ministries, editorships of technical journals and so forth. A professor may also accept as many short-term industrial consulting contracts as he can fill without interference with his official duties, and standards here appear to be rather broadly applied.

Besides a second regular job and consulting assignments, many professors engage in textbook and monograph writing, which is paid at the rate of 100 to 200 rubles per page, the figure depending on whether the manuscript is accepted as a textbook and on the number of copies printed. Since this gives a fee of tens of thousands of rubles, it is a significant source of income even when it is split among several authors. Other sources of income are prizes for technical achievements, additional salaries for Academicians (2,500 rubles per month) or Corresponding Members of the Academy (1,500 rubles) and others. Altogether, it is estimated that the average income of a Soviet professor is 7 to 10 times that of the semi-skilled worker.

The working year of the Soviet faculty member is 10 months. Although many scientists use one of the two months' vacation to do research, write or consult, most schools and research institutes are officially closed in July and August. The laboratories may be used by professors for their research during this time.

The normal working day is six hours, and there are six working days per week. Of this total of some 1,500 hours per year, a professor is expected to spend 500 to 600 on his teaching, 500 to 600 on research and the rest on writing, consulting, editing or as he sees fit. The teaching load of a docent is somewhat higher, varying from 720 to 840 hours.

The teaching load includes 100 to 200 hours of lecturing, which is equivalent to three to six hours per week, and, in addition, student counseling, laboratory sessions, thesis and project supervision and the preparation of notes for lectures. Final examinations are an additional heavy load; they are all oral and last 40 to 60 minutes. Since a course may well have 100 or more students, the examinations take several full days' works twice a year. But in general, except for thesis defenses, the professor leaves the bulk of that load to his assistants.

V. UNDERGRADUATE STUDENTS

The five to 5½ year curriculum leading to the diploma in engineering is the basic preparation for engineering in the USSR. The basic entrance requirement is completion of the ten year secondary school. Graduates of technicums in the upper 5% of their class are also permitted to apply and under certain circumstances may be excused from the normal minimum three year work period required of technicum graduates. A maximum age limit of 35 years is reported. Certain other special situations pertaining to previous educational experience and family circumstances also exist.*

There are competitive entrance examinations which, for engineering students, are given in physics, chemistry, mathematics, one foreign language and Russian. Students must apply to a specific faculty of a specific school, and may apply to only one place in a given year; this is insured by requiring that the original high school transcript be attached to the application along with an autobiography, work and party activity record, and letters of recommendation.

* Alexander G. Korol, *Soviet Education for Science and Technology*, Technology Press and J. Wiley & Sons, N. Y., 1957.

Admission Requirements

The entrance examinations in physics, chemistry and foreign language are oral, the Russian language examination is written and the mathematics examination consists of a written and an oral part. While these examinations are uniform across the country and based on the ten year school curriculum, they are graded by the faculties to which the students have applied, which may allow a difference in standards of evaluation to enter the picture. The preparation of Soviet students in mathematics and chemistry appears to be comparable in level but somewhat broader in coverage than that of the applicants to leading U. S. engineering schools. In physics, the average Soviet students appear to be appreciably better prepared than our best.

In order to fill their available vacancies, Soviet schools rely heavily, but not exclusively, on grades of the entrance examinations. In general, to be considered for admission, an applicant must have a grade better than a certain minimum set by the faculty to which he has applied. The minimum varies from faculty to faculty and from school to school, and is

generally set so as to pass a number of students somewhere near 130% of the number of vacancies. Since there are five examinations and the Soviet grading system goes from 5 (excellent) on down, 25 is a perfect grade. Typical cutoff grades vary between 23 (Physical Chemistry Faculty of Mendeleyev Chemical Institute in Moscow; Automatic Control Faculty of Moscow Power Institute) and 18 (Automobile Maintenance Faculty of Frunze Polytechnic Institute).

The other criteria considered for admission are work record, impression made by the student during a personal interview, and national origin and background.

Since 1955, it has been Soviet policy to give preference for admission to those applicants who have at least two years of industrial experience, the hope being that 80% of admissions would be in this class by 1958. The admission figures for 1958 show that 32% of the students admitted by the Bauman Institute had two years' experience, 28% at the Moscow Power Institute, and 25% at the Moscow Aviation Institute. On the other hand, the Kuibyshev Aviation Institute admitted 45% with such experience and the Frunze Polytechnic Institute 55%. Academically outstanding schools have been apparently reluctant to comply with the new policy.

The applicants' examination records, their high school records and work experience, as well as their supporting documentation (biography, passport, police certificate of law-abiding living, medical certificate, recommendations) are examined by the school admission committee, which consists of the Director or a deputy, the deans, a responsible secretary who must be a professor, and representatives of local social, professional and political organizations. Each applicant with an acceptable examination grade must then be interviewed by a member of the committee, and the final selection is made on the basis of personal impressions about the applicant's seriousness of purpose and suitability of background.

Although a student may apply for only one field of specialization in one VTUZ in a given year, the number of applications that are received for admission to the various schools and specialties is announced and students are guided accordingly. If a student fears competition, he may apply to a school where applications are known to be few, and to avoid further competition he may even apply for a specialty other than that of his first choice.

The students are well aware that a diploma from a second choice school in a second choice specialty is preferable to no diploma at all, in view of the opportunities for advancement which a diploma affords. The list of applicants to all faculties are public and most youths are fairly realistic about their probable chance; they will therefore shift their applications just before examination time to an optimum balance between vocation and chances of admission.

At the time of admission a student commits himself to one specialization. On graduation there is essentially no choice other than work in the industrial area for which the student has been prepared by his specialty. There is little freedom for transfer between major engineering areas or specialties during the educational career of the student.

The Soviet educational system does not provide higher educational opportunities for all who seek them. On the contrary, the number admitted is dependent upon the needs of industry as forecast in the five year plans. Currently the ratio of applications to

admissions is in the order of 3.5 to 1. This ratio, however, varies with the popularity of a given specialty and the reputation of the VTUZ. For example, at the Institute of Civil Engineering in Moscow, the ratio of applications to admissions was 9 to 1 last year. At the Leningrad Polytechnic Institute 1,500 were admitted from an application list of 4,000. At the Bauman Institute in Moscow, the ratio was reported to be 2.5 to 1. These data relate to the day programs.

The situation is different in this respect in the evening and correspondence schools, where almost all the students have industrial experience and are working. These adult education programs help raise the qualifications of practicing engineers and administrators who do not now have the formal background required for their jobs. The standards required are admittedly somewhat lower than in the day schools, and competition is less severe. These programs are expending rapidly and are making a significant contribution both to the Soviet economy and to the art of engineering education.

Student Housing

All the institutions which were visited were in cities, and in most cases the institution buildings were scattered throughout the city, with few campuses in the sense that there are campuses in the United States. However, at Frunze the Polytechnic Institute is building what will amount to a campus, and at the Kalinin Polytechnic Institute in Leningrad there is a good campus. In general, dormitory facilities are available for from 30 to 40% of the students, whereas the rest live in the city, usually at home or with relatives. Student eating facilities are usually provided in the "house of culture," which is the equivalent of a student union in the United States. Apparently good, nourishing food is available at reasonable prices for the students.

Dormitories appeared to be built to a standard pattern with a room approximately 11 feet by 16 feet being provided for four students. The usual furniture in such rooms consisted of four single cots, two on each side wall; a central study table; two chests of drawers; sometimes an alcove to hang coats in, but not always. The boys made little attempt to decorate the rooms except with a few minor pennants, whereas the girls used window drapes and decorative covers on the beds. Any decoration was done entirely by the students; all other items were provided by the State.

Student Finances

Lack of financial resources does not stand in the way of higher education for anyone. From 85 to 90% of the students are given grants based on need and aptitude. The first-year students normally receive 300 rubles per month for 12 months, fifth-year students get 500 rubles per month. Honor students obtain an additional 25% above the basic grants, and it was reported at one VTUZ that 35 to 40% of the students qualified for these bonuses. In addition to these grants the Ministry of Higher Education provides some special grants for superior students. At the Leningrad Polytechnic Institute, it was reported that 200 such special grants were available, which was more than enough for all who qualified. Accordingly, not all of those available were assigned.

Student grants are awarded by a special committee of the faculty, which includes some student representation. Although need is a consideration, students of superior ability may receive grants regardless of need.

The amounts of the grants are suf-

ficient to take care of subsistence (food and lodging). The standard cost of rooming is 15 rubles per month, including linens. The ordinary grant, however, will not take care of clothing, which is relatively expensive. A suit costs from 400 to 1,500 rubles; a pair of shoes, from 60 to 300 rubles.

The School Year

The school year, uniform throughout the USSR, extends from early in September to the third week in June, for a period of just less than 10 months.

The VTUZ's operate six days a week and the normal work load for an engineering student is six hours a day or somewhere between thirty and thirty-six hours a week. Lectures are for two-hour periods, and for most institutions cover the hours from ten to four. Laboratories vary from two- to four-hour periods, and laboratory sections are in operation at most institutions from eight a.m. to six p.m. Most recitations and discussions occur in the laboratory sections, which are made up of from 15 to 25 students. Lectures are held for between 100 and 200 students.

Extracurricular Activities

Each VTUZ has an administrative officer whose function is roughly that of supervisor of the "house of culture" or director of the student union, plus responsibility for the various other student activities. Extracurricular activities, however, are run largely by the students. These include professional clubs, swimming organizations, drama groups, music groups, and sports consisting of tennis, basketball and football. The Komsomol (Young Communist League) is quite active in promoting extracurricular activities at all the institutions of higher learning. It is important to note that while extracurricular activities are encouraged, they are decidedly secondary in the student's mind. Doing well in his studies is the first and absolute requirement. At the Kalinin Institute in Leningrad, for example, there is a statue called "The Laggard Student." Students who fail to do well in their work are hazed by their fellow students before this statue.

Student Motivation

Under a system that attaches so much importance to the diploma and one in which competition for admission to an institution of higher learning is so severe, it was not surprising to find an attitude of grim determination among the students. One sensed that they had a high regard for scholarly achievement and a disdain for the laggard. In this atmosphere the rate of attrition was found to be unusually low. For example, at the Leningrad Polytechnic Institute it was reported that only 8 to 10% of those who are admitted do not complete diploma requirements. At the Moscow Power Institute only 10 to 15% of the students who enter do not finish. These figures apply only to the students enrolled in the day divisions. For those enrolled in the evening and correspondence divisions, the attrition rates are much higher. For these categories it was reported to be 50%.

Job Placement

Placement is handled by a committee which includes the dean, the local unions, the representatives of Komsomol, and the industrial organizations seeking engineers. In general, in an open session, the committee decides on the jobs. The decisions depend upon four points: 1) the recommendation of the dean, 2) the health of the student, 3) family needs, and 4) the desires of the student. The

best students are sometimes encouraged to continue as graduate students, but this is permitted only in exceptional cases, since normally a student who does graduate work is expected first to go into industry for at least 2 years. The general policy is that even if a student wants to go into research, he should have some industrial experience. When several students want the same job, preferences are usually determined by the dean's recommendations or the family needs. The diploma projects (see curriculum section) are often associated with activity at some particular industry. In such cases, the student may be assigned to that industry unless other needs are much more pressing.

After assignment by the Ministry, a student is given a month's leave and salary and expenses for himself and family to settle in the new place. A local group will help to get him settled. Job assignments are made only to the first job. After that, it is up to the director of the industry which employs him. A good director will rotate his men to find the places where they fit best within the area of the specialty for which they were trained. An evaluation of engineering graduates is made after three or four years in industry, and studies are made as to whether the graduates are happy and are treated well. There is also a follow-up system concerning the value and utility of the courses which they had at the VTUZ.

VI. CURRICULA

The most dominant characteristic of engineering curricula of the USSR is the high degree of specialization. An examination of the various study plans for a typical cross-section of curricula will indicate that specialization begins almost from the day the student enters the VTUZ. Although the first two years are devoted to a study of the basic sciences and mathematics, even these courses are oriented with respect to the specialty in which the student is enrolled. As he progresses, course work becomes more and more specialized. Soviet engineers are trained in nearly 200 different specialties spread over some 20 broad areas (Appendix C).

The emphasis on specialization is considerably strengthened by the fact that out of 187 engineering schools only 29, or less than 16%, are Polytechnic Institutes similar to our Institutes of Technology, where several fields of engineering are taught at a single campus. The majority of Soviet engineering students attend VTUZ's where only one field is taught; they go to a Mining Institute, or an Aviation Institute, or a Railroad Transport Engineering Institute. Appendix D gives a breakdown of Soviet engineering schools, of which there are over 25 classifications.

The curriculum extends over a period of five years for most schools, 5½ for a few special schools, or curricula, six years for evening or correspondence school. Most students who complete the correspondence course, however, take 8 to 10 years. Typical curricula both for five and 5½ year programs are given in Appendix G.

While the general pattern of the basic science course is the same for all Soviet engineering schools, the amount of time and attention given to any specific subject varies with the specialty and the school. For example, the mathematics course always covers a four semester span and concerns itself with analytical geometry,

differential and integral calculus, and introduction to differential equations. But students in mechanical and electrical specialties, in most schools, cover this material in 400 hours, while civil engineering and mining engineering students do it in 300 hours. Furthermore, at the Bauman Institute and the Moscow Aviation Institute, there are 450 to 500 hours devoted to the subject, and the coverage includes plane analytic geometry and differential calculus (1st semester); analytic geometry in space and integral calculus (2nd semester); elementary differential equations, functions of several variables, line, surface and volume integrals (3rd semester); power and Fourier series, introduction to fields and vector analysis (4th semester).

Integration with High School Programs

A typical physics course lasts three semesters and takes some 245 hours; it covers molecular physics, heat, sound (2nd semester), optics and electricity (3rd semester) and modern physics (4th semester), though again variations in detailed course content were observed. In general the physics courses are well-integrated with the high school. The delegation found an experimental treatment under way at the Bauman Institute, where the course gave a rather brisk survey of classical physics and electricity (2nd semester), physical optics, statistical mechanics and quantum theory (3rd semester) and nuclear physics (4th semester).

General chemistry seems to be taught at a high level with little descriptive material. Reliance is placed apparently on the high school chemistry courses to take care of the descriptive nature of the courses. However, general chemistry is not as broad as might be expected. For example, at the Bauman Institute the first semester of the first year is devoted to a strong course in general chemistry which moves rapidly and is built on the good background of the ten year school. However, the second term is slanted definitely toward the chemistry of metals, since that is one of the major objectives at this VTUZ, and other topics in general chemistry are either ignored or treated lightly. In those VTUZ's which have specialties in the area generally called chemical engineering in the United States, general chemistry is much broader and more comprehensive, but even here the specific examples in the first year are tailored toward the student's eventual specialty rather than to illustrate general principles.

Curriculum Pattern in VTUZ's

The first two years are generally devoted to a common core which includes basic sciences (mathematics, physics, chemistry and mechanics), basic skills (drafting and machine shop), and non-technical material (foreign language, study of Marxism-Leninism). The third and part of the fourth year are used for applied sciences (thermodynamics, metallurgy, electrical science, etc.), introduction to design (detail machine design, simple circuits, etc.) and some further social disciplines. The fourth and fifth years cover increasingly specific material concerned with the hardware around which the specialty of the student is built, including design, performance and production characteristics. The curriculum is concluded with a "diploma project" carried out by the student. There are also included three periods of industrial practice after the third and fourth year and just prior to the diploma project; these start with general factory experience and are coordinated more and more with the specialty during the last years.

Teaching of basic science courses is done by professors in lectures to large groups of 100 to 200 students (55% of the contact hours) and in recitation periods for groups of 25 to 35. In all cases, the students attend separate recitations according to specialty. An attempt is also made to do the same with lectures. This practice makes possible differences in emphasis and time allotment for different fields and allows the introduction of many examples from the student's specialty to illustrate basic principles.

A standard Soviet lecture lasts two hours with a ten minute break in the middle; it is rather formal and students seldom interrupt to ask questions. These are either submitted in writing or saved for the recitation period.

The recitation period is usually conducted by an instructor or assistant; it involves answers to questions, problem solving on the blackboard, and discussion of homework problems. It should be noted, incidentally, that although the Soviet students have more contact hours than Americans do, they have less homework. What homework we saw was quite similar to the problems assigned in the United States.

One very significant factor is that every professor in a teaching institution, whether it be an engineering institution or a university, teaches at least one course to students who are undergraduate or candidates for their diploma, and no professor teaches more than two such undergraduate courses. The one exception to this is that in some of the service departments, like mathematics, physics and chemistry at the VTUZ's when these courses do not represent diploma courses, the professor may teach three courses. If a professor does not wish to teach an undergraduate course he must seek a job at a research institute rather than a university or VTUZ.

Laboratory instruction plays a dominant role in Soviet engineering education. Recitations commonly occur in the laboratories also. The laboratories are conducted in groups of 12 to fifteen students. The students work most of their problems in the laboratory discussion periods. There seem to be fewer homework problems than are assigned in the United States. In the small sections that were observed, there seemed to be good interchange of questions and answers and discussion among students and the teacher. Laboratories are handled by assistants and docents, but the supervision of each course is, wherever possible, under a professor. In some of the institutions there was a docent acting as professor, but it was said that this was because of the shortage of professors.

In the fourth and fifth years the students are often given a course project, which is really a comprehensive problem which the student works on his own, both at home and in laboratory periods.

In the first and second years in the laboratory the student gets specific instructions and goes through standard experiments. This seems to be particularly true in lower division chemistry and physics. In the third, fourth and fifth-year laboratory courses, where more professional work is given, students are given more general instruction. They often build the experimental equipment instrument for the experiment and in general learn how to do more creative work.

Extensive use was made of high quality teaching aids, and great ingenuity was apparent in the developments of these aids.

In physics and chemistry, the students also have a laboratory where they are given detailed instructions for setting up the apparatus and making measurements, and preparing a

report according to an outlined pattern.

Even as early as the sophomore year the laboratory courses, in addition to being designed to illustrate principles in the laboratory, have specialized application techniques aimed at the particular specialty in which the student is majoring.

Students are expected to be proficient in the manual arts related to their specialties; for example, one specializing in machine design is trained in the operation of various machine tools and a considerable amount of time is devoted to developing this art. Typically, a curriculum will specify 250 hours for this purpose. During this time, the student works in a laboratory as a workman; that is, as a welder, a machine tool operator, a bricklayer, etc., depending upon his specialty.

In examining student work, one cannot help but be impressed with the high degree of proficiency in drafting that is exhibited. In accordance with the Soviet system of engineering education, it is not sufficient only to know the principles of drafting, it is also necessary that one become a skilled draftsman. To this end, students are required to begin courses in drawing in the secondary schools. It is offered in the seventh, eighth, ninth, and tenth grades. Upon entering the VTUZ, the student usually continues with four more years of drafting.

Examinations

The general pattern of examinations at the end of the year is to have one comprehensive examination covering all the year's subjects. This examination period is supervised by the professor who is head of the chair in the specialty in which the student is registered. He is assisted by his docents and assistants. There seems to be a growing pattern of giving course examinations in each course at the end of the year. This is being tried out at certain leading schools and is now in operation at both Lensoviet Institute of Chemical Technology and the Mendeleyev Institute of Chemical Technology. It was said by the staff at those institutions that this procedure was working quite successfully. They expected that the pattern would spread on a national basis before too long.

Industrial Practice

The first industrial practice period comes after the third year and serves to acquaint the student with industrial operations. The student is assigned as a semi-skilled worker in a number of shops and departments, and no special effort is made to fit him to a job related to his course.

The second industrial practice period comes after the fourth year. The student is assigned to one or at most two positions which in principle should be related to his field; his work is that of a skilled worker, sub-professional technician or assistant foreman; he is not given any responsibility except to watch a permanent staff employee to whom he is attached or occasionally help him.

The last industrial practice period comes after the ninth semester for a five year school, after the tenth for a five and a half year school. The students have now completed their formal course work and are assigned as junior engineers, in their specialty whenever possible. They usually are assigned an independent job related either to product design or to plant operation; this prevents their interfering with normal factory work, occasionally leads to useful new ideas and helps the student find a thesis (or diploma project) topic. The last industrial practice period is often an opportunity for the student to make contacts which will eventually lead to

his job assignment and is therefore considered very important. Students at industrial practice are paid the going wage for the type of work which they perform.

In general, each school has agreements with a number of plants and projects concerning such industrial practice assignments; for example, the Bauman Institute has 300 such correspondents; an attempt is usually made to select leading plants for this purpose so that the students become acquainted with the best current industrial practice. On the other hand, this arrangement gives leading factories an advantage in selecting the better prospective graduates, since they get a preview of the whole crop.

The Diploma Project

The last part of the curriculum is the preparation and defense by the student of a "diploma project" or thesis. The entire last semester of his schooling is devoted to that task and even evening and correspondence students must take a leave of absence and go on full-time study for that purpose.

The diploma project is an individual design of a piece of hardware, a study of an industrial process, or for a few top students a piece of research.

Typical diploma projects might be the design of a gas turbine propelled locomotive, the design of a dam and hydroelectric power station at a specified location, the automation of the production process of a television tube. The subject for this project is generally selected by the student himself, often as a result of his pre-diploma industrial practice session and sometimes with financial support from industry.

In general, it consists of complete drawings which represent the proposed assembly and details of the main components, plots of performance as required and drawings of required tooling arrangements. There is also a 100 to 200 page report which discusses and analyzes the project. The report generally includes an introduction which stresses the potential use of the proposed item; in almost half the projects inspected by the delegation, the introduction quoted Lenin, Krushchev or the proceedings of the 20th Congress of the Communist Party. The analysis of the project includes four sections: performance (thermodynamic cycle of a power plant, aerodynamic performance of an aircraft, power and frequency output of an amplifier, etc. . . .), stress analysis of the main moving parts (rotor disk and blading of a turbine, wing section of an aircraft, etc. . . .), analysis of production techniques to be used and economics of operation.

At the Mendeleyev Institute of Chemical Technology in Moscow about 50% of the diploma projects were subtasks of the professor's research, and about 50% were design. In the curriculum in paint and varnish, one diploma project was the design of a plant for the manufacture of a dull varnish. This is a typical project resulting from the student's work experience. On the other hand, a student in the curriculum in inorganic substances did his diploma project on a phase of the kinetics of the reaction between potassium iodide and silver iodide at 100 atmospheres. There is a planned connection between the diploma project and the last industrial experience. This often determines the employment of the student after receiving his diploma. The former student may go to work for the paint plant; the latter may get a job as a research assistant at a research institute.

All the diploma project reports examined were entirely handwritten; the reason given for this was that this

is the only way to insure that the student actually performed the work.

On completion of the course of study, the student is required to defend his diploma project before a state examining committee. The committee is appointed by the Ministry of Higher Education and consists of some eight to ten members. Its chairman is invariably a leading engineer in the field of the specialty involved. The other members include the dean, the professor of the specialty involved, the project supervisor, and other academic and industrial members.

The defense consists of a 20 minute presentation of the results of the diploma project by the student, followed by questioning by the committee, with the whole examination lasting about an hour. In general, these defenses are public and questions from the floor are authorized. The questioning may bear directly on details of the project and also on the course material of the curriculum. Very few students fail at this stage because unsatisfactory projects are not brought to defense, but an outstanding defense may well help the student's later career.

Changes in Curriculum

Minor changes in course content which do not disturb the general course organization may be introduced continuously by the various professors; the course outline prepared by the ministry specifies the minimum content; any chair may add to it.

More significant changes are introduced, generally as overload electives at first, by a few leading institutions. Eventually, hand-tailored, individual curricula including such new material may be authorized at these institutions by the Ministry. For instance, the Bauman Institute curriculum for turbine design is different from the general curriculum in the same specialty; the Moscow Power Institute has recently introduced a course in atomic power stations which is not taught anywhere else. Apparently, such initiative is expected and encouraged, this being considered a normal responsibility of schools with outstanding faculties.

Another channel, in addition to initiative by leading schools, which serves for the introduction of new material into the curriculum is the conference called by the Methods Division of the Ministry of Higher Education every few years. Here, Ministry officials, teachers, and industrial representatives examine course content, curricula and teaching methods in specific fields and make recommendations for major revisions. Such conferences lead to new textbooks and major reforms, but apparently their workings are slow.

Student Initiative

The matter of freedom and initiative for students is closely related to staff quality. In their educational literature, the Soviets claim that the development of individual initiative in the student is one of the aims of their laboratory-project system of instruction. Some schools, such as the Moscow Aviation Institute, follow this by allowing third-year students one day a week and fourth and fifth-year students two days a week without scheduled classes as long as they keep up high scholastic records. The better students are permitted to replace some of their term projects by participation in actual sponsored research projects of the staff. Similar arrangements were observed at other VTUZ's in Moscow and Leningrad. In general, except in these leading schools, such opportunities are less likely to arise because the staff has less equipment and fewer contacts for sponsored research.

Evening and Correspondence Programs

Evening and correspondence course students combine part-time education with essentially full-time industrial work. The evening students work a six-hour day, followed by four hours of classes in the evening from seven to eleven, and complete a regular five year course in six years. In addition to the lectures during the academic year, a one month full-time period is required each year for laboratory courses and examinations. This is provided at full pay in addition to regularly scheduled vacations.

The same facilities are often used by day and evening students. Apparently some, but by no means all, of the day staff teach evening school, and a number of part-time teachers selected from among leading engineers do much of the evening teaching, especially in the specialized fourth and fifth year courses.

While the general course content is supposed to be the same in day and evening school, it is found that basic sciences (mathematics, physics, and chemistry) may not be at as high a level. Evening students who are employed do not receive scholarship support. They have little opportunity to take part in extracurricular activities.

Correspondence course students carry on a program only remotely related to that offered by correspondence schools in America. The Soviet correspondence curricula are about the same as those for evening students, with the correspondence replacing the regular lectures and homework. They lead to a diploma considered equivalent to diplomas from the regular day program. Each year the student is entitled to an educational leave with full pay plus expenses, during which period all laboratory work and examinations are given.

The correspondence program is one of the most rapidly expanding features of Soviet engineering education. It is administered primarily by some dozen correspondence institutes in Leningrad and Moscow serving the entire Soviet Union. A special feature is a network of teaching and consultation locations. For example, the Moscow Extension Polytechnic Institute has 31 such centers in Kuibyshev, Irkutsk, Yakatak, Vladivostok and other cities. Skeleton staffs are available at other centers for advising students and conducting a limited portion of the lecture, laboratory and examination program.

The operation of correspondence programs was observed in some detail at the Moscow All-Union Extension Polytechnic Institute. Each of the 36,000 registered students at the Institute has a file to his name in which the record of his progress is kept; the dates at which he mailed in his homework, the grades, and other remarks are filed there. The student must satisfactorily solve every assigned problem; if wrong solutions are turned in, the correspondence instructor comments in detail on the mistakes and sends the paper back within five days. When all problems in a course have been solved correctly, the student may petition for an examination; that examination may be given at any time of the year either in Moscow or at any of the 31 consultation points established throughout the USSR. If the student falls far behind his due date, a reminder letter is sent to him; if that is not sufficient, a second reminder is sent to the student and a letter is also sent to his supervisor. The total correspondence load is reported to be 450,000 items yearly or over twelve per student.

In order to help the student with his work, the Institute sends him a good deal of material free of charge. This includes instruction sheets about how to organize his work, problem sets, text-material. If he lives near

a consultation point or works in an area which has many such extension students, the Institute organizes lectures on the spot, using either staff from local schools or senior engineers; these are approximately 25% of the number of lectures of the regular curriculum and must cover the essential points of the same material. If the student is in an isolated locality, he cannot attend such lectures. The staff of the Institute prepares outlines of the lectures which are far more detailed than the textbook and are kept up to date. These are sent to the students. In addition, the students receive sets of sample problems with step by step solutions, old sets of quiz problems and lists of references and background material every year.

Laboratory courses are taken during summers at the nearest school which has the appropriate facilities; the student's employer is required to give the student an extra month's paid leave and transportation for the purpose of taking these courses. The last half year is devoted to a diploma project which is generally done in Moscow and for which the students must enroll full time.

The growing importance of this form of education is demonstrated by the fact that until three years ago there was no admission competition; since that time facilities have doubled and yet only 40% of the applicants are admitted. This extraordinary growth from 8,000 applicants to 40,000 applicants per year in engineering is not unrelated to the fact that some 180,000 young people every year fail to gain admission to a regular engineering school. It was stated that nearly 50% of those admitted eventually graduate from the system.

VII. FACILITIES

It is an understatement to say that the buildings provided for the VTUZ's are in general of poor quality by American standards. Housing of all types is critically short throughout the USSR and new building construction is in evidence everywhere. Because of the extreme shortage, emphasis seems to be placed on quantity rather than quality and workmanship is crude in comparison with U. S. standards. In this regard, it has been said that the Soviets have a knack for building old buildings.

Crowding of school facilities is understandable when one realizes the desperate need for domestic housing. To alleviate shortages in this most basic need, it was reported that a quota of 1,000 new apartment buildings had been established for the city of Moscow for each of the past two years. These apartment buildings occupy the major portion of a city block. Even with this extensive amount of building, however, the space allocation is no more than 9 square meters, some 100 square feet, per person.

Under these circumstances, many of the VTUZ's are housed in very old buildings, the state of repair of which leaves much to be desired. Plumbing and electrical facilities are very noticeably poor. Lighting, generally, is much less than adequate. Limitations of space result in excessive crowding, and hallways during the intervals between classes remind one of Grand Central Station during rush hour.

Laboratories

Inasmuch as laboratory instruction constitutes a vital part of the Soviet educational pattern, laboratories were in general found to be both numerous in quantity and excellent in quality.

The equipment was found to be in good state of repair and working condition, and a good variety of equipment is available. It is noteworthy that much of the older equipment in these laboratories is of foreign manufacture—Swiss, German, English, as well as American. The newer equipment, however, appeared to be mostly of local manufacture and it appeared to be of excellent quality.

What has been said in general of laboratory facilities is not applicable to all institutions that were visited. Variations do occur, as might be expected. The newer schools were not as well provided for as were the older, well-established institutions.

The laboratories are in general of two types—laboratories used exclusively for teaching, and research laboratories. The Delegation was especially impressed with the variety of ingenious teaching aids that were frequently found in such laboratories. The research laboratories are used primarily for research in which the staff is engaged. They do, however, also serve a teaching function. Students of superior ability are given the opportunity of participating in such research endeavors.

The VTUZ's are liberally provided with supporting shops and facilities for the construction of test equipment and special apparatus. Much of the equipment to be found in the laboratories was fabricated in the VTUZ's own shops. It was also evident that professors have a generous number of technicians to assist them with research endeavors. Thus it appeared that the role of a staff member engaging in a research project is one primarily of giving top-level direction to it.

Libraries

Although library resources varied from institution to institution, those of the distinguished schools were impressive. For example, the Leningrad Polytechnic Institute claims a collection of some 1,500,000 volumes. In addition, it was noted that the public library of Leningrad has a collection of 13,000,000 volumes, although it was not well organized for use, and some of the library services seemed deficient. Many English language books and current English periodicals are to be found. From this evidence and discussions with members of the faculty, one gained the impression that the engineering fraternity of the USSR is well aware of developments in engineering technology outside the Iron Curtain. Members of the U. S. Delegation had on various occasions opportunities to meet with specialists in their own field of competence. From discussions with these people, it was abundantly clear that the Soviet engineer is much better informed of developments in the U. S. than his counterpart is of developments within the USSR. This may in no small part be due to the very effective translating and abstracting services that are provided and the ability of many Soviet engineers to read English. It was reported that a translating and abstracting service, employing approximately 100 people, is available.

Museums

The heritage of the past is well preserved in the museums that are to be found not only in the educational institutions but also in other government museums throughout the USSR. Among the most impressive of the government museums that were inspected are the Armory Chamber Museum in the Kremlin and the Hermitage Museum in Leningrad. Here are to be found treasures of art that will compare with the finest anywhere. For example, the collection of paintings in the Hermitage includes

no less than 20 Rembrandts and 42 Reubens. But as impressive as are the collections to be found in these museums, even more impressive is the use to which they are being put. They are not storehouses to be forgotten and left unnoticed. On the contrary, they are well attended by all classes of people. Especially noticeable are the groups of children on conducted tours, listening attentively to their guides. These observations lead one to believe that the museums serves a vital role in the education of Soviet youth.

Outstanding among the educational museums is the Railroad Museum at the Institute of Railroad Transport Engineers in Leningrad. This museum, founded in 1813, contains a most impressive collection of bridges and locomotives, depicting the chronological development of these facilities. Also in this museum were some of the latest rolling stock and material handling equipment. There can be no doubt that the availability of such collections serves to generate interest and inform the student effectively of technical developments.

VIII. ADVANCED DEGREES AND GRADUATE STUDY

Graduate study in engineering plays an increasingly important part in American engineering education, where it fulfills the triple function of preparing new teaching staff, filling the need of the economy for applied scientists and forming a unique vehicle for the carrying out of considerable basic research in engineering science under circumstances which allow its results to influence the education of young engineers with minimum delay. As a result, some 10% of our engineering students do at least one year of graduate work and some 2½% eventually get a doctor's degree.

The situation is quite different in the USSR. In engineering education which is meant to supply the economy with engineers, the diploma is considered terminal and is not considered a degree. Graduate enrollment is somewhat under 1% of the total (some 4,600 out of a total of 580,000), with an additional 4,800 working at research institutes. Leading schools like the Bauman Institute have some 200 graduate students in an enrollment of 10,000; Kuibyshev Aviation Institute reports 7 graduate students in 3,000.

Engineering graduate enrollment is planned to supply the educational system with its required teaching staff and to provide for the needs of the engineering research apparatus. While research is discussed in greater detail in Section IX, it should be stated at the outset that the two streams are somewhat separate. Research done in engineering institutions (VTUZ's) is generally what would be termed development in the U. S.

Graduate study in science and engineering in the USSR is built around the relationship between student and research supervisor. The assignment of graduate study slots to various institutions is made on the basis of the availability of a thesis supervisor. This means, for example, that if at a mining institute there is only one senior staff member whose standing enables him to suprevise a thesis, and his field is the theory of plates and shells, there will be no graduate study in mining, but only in the theory of plates and shells; and if such an individual retires or goes elsewhere, the VTUZ will lose the privilege of hav-

ing graduate students. In order to supervise theses, a staff member must be a docent or a full professor.

Since the availability of a supervisor is the essential factor, research institutes which do no undergraduate teaching may and often do have graduate programs built around their senior staff; in fact they now do roughly half the graduate training in the USSR.

Graduate programs lead to two different degrees: the degree of "Kandidat Technicheskikh Nauk" (Candidate of Technical Sciences) which may be compared to an American doctorate and the degree of "Doktor Technicheskikh Nauk" (Doctor of Technical Science) awarded for major technical contributions.

Degree of Kandidat

The degree of kandidat requires a certain number of courses and examinations and a research thesis; it may be pursued either in residence or by extension, and a set academic program and pattern is involved in obtaining it. The doctor's degree involves no formal study but only the defense of a thesis.

In order to be admitted as a resident graduate student, a Soviet citizen must have completed a recognized undergraduate course and the compulsory work assignment which follows. A very small number indeed of engineering students are admitted to graduate standing immediately after getting their diploma. A larger number of outstanding students tabbed by the staff as graduate school material are assigned to research projects either at their own school or where close contact can be kept with them.

Applicants for graduate school are selected by means of an "entrance investigation" rather than by an "entrance examination" and in view of the small number of people involved and of the intimate relationship between student and professor, that investigation is generally very informal; the examining committee consists of the dean or institute director, the professor in charge of the chair or laboratory director and the prospective thesis supervisor; the investigation covers the fundamentals of the discipline in which the thesis is to be done and preliminary ideas of what the thesis should cover and how it should be attacked; if the prospective supervisor is satisfied, the rest of the committee generally goes along. There is in addition an examination in one foreign language and in Marxism-Leninism, although these are usually formalities. In general, one out of every two or three applicants is accepted, although room can always be found at this level for an outstanding prospect.

After his admission, the graduate student receives a stipend which is roughly double that of an undergraduate (800 to 1,000 rubles per month); student housing and other privileges are available to him; he has access to a semi-private study room in the library and to the necessary shop time or laboratory equipment.

His study program is laid out on the basis of three years' work as follows. First, he must pass examinations in a number of subjects, including Marxism-Leninism and a foreign language. Universities and VTUZ's offer one year courses in these subjects and conduct state examinations every May. These courses each require two hours of lectures and two hours of seminar a week. For the first two years, the student also studies in his field, in which he must pass three examinations, usually scheduled in May, 8 months after he entered graduate school. To prepare for these tests, he may either attend a suitable course if it is offered, which happens

only in the larger towns or VTUZ's, or attend seminars in the field, or study by himself with consultations with staff. Half of the material covered in these examinations is general background material and half bears specifically on the area of the field with which the thesis is concerned. For example, if the student is preparing a thesis on the performance and design parameters of hypersonic test facilities, his first examination would be in aerodynamics and gas dynamics, the second might be on problems of flows in pipes and tubes and turbines, and the third might be on aerodynamic measuring techniques and high-speed data recording methods.

These two general and three technical examinations correspond to the doctoral qualifying examinations generally given in American schools. The technical examinations are taken orally before a committee of six to eight professors of the faculty involved, and an appraisal of performance is written into the aspirant's record and signed by all committee members.

After this series of examinations has been completed, the student starts his research program. Once the thesis topic is determined, he is expected to devote all his available time to research except for attendance at seminars, and to report on progress at least once every six weeks.

Until 1957, the total time available to a full time graduate student was three years; if he had not defended his thesis within that time, he was denied his degree. Graduate students devoting part of their time to teaching or research were not held to this limit. There is now no fixed time limit, and one is told that a period of four to five years is not uncommon in the natural and technical sciences. This is due partly to new rules designed to improve the quality of the theses by subjecting them to more thorough scrutiny before admitting them to defense.

A prospective thesis or its summary must be accepted and published in a recognized technical journal before it is considered complete. Since the time lapse between submission and publication of a manuscript is eight to sixteen months, here is a first uncontrollable delay. After publication, 150 copies of a summary of the thesis are prepared and mailed at State expense to various experts in the field who send in appraisals to the dean of the faculty or the director of the laboratory involved. This is done one month before the scheduled defense of the thesis.

The defense of the thesis, which is the key step in obtaining the degree, is a public presentation of his results by the aspirant before the academic council of his institution. It is announced ten days in advance in the local press, with title, aspirant's name and the names of the two "official opponents" selected by the academic council to lead the discussion of the work presented. The discussion may involve not only the official opponents but also other members of the academic council and of the audience. In general, it lasts three to five hours, although some have been known to take several days. After the discussion, the academic council votes by secret ballot whether to accept the thesis. For approval, the thesis needs a two thirds majority of at least two thirds of the full membership of the academic council.

When an aspirant's thesis has been successfully defended before the academic council, the Higher Attestation Commission (VAK) (Section III) is notified and it must give its approval before the kandidat's degree is awarded. VAK assigns the thesis to one of its standing committees of

experts who are professors at various schools and research institutes. Unless they object, the degree is granted and signed by the chairman and the secretary of the academic council involved. If there are objections, the aspirant is invited to defend his thesis again before the VAK expert commission; VAK disqualifies 1½% of all theses submitted to it. If this happens, the thesis must be rewritten and re-submitted. Even if VAK approves the thesis, the procedure of publishing, sending out summaries, defending and getting VAK approval takes 18 to 24 months after the completion of the work.

Since few graduate courses are offered, there is no particular need to be in residence at an institution of higher learning to qualify for a degree. If a qualified supervisor is to be found at a research institute, the graduate study program may be carried on there just as well. This is done with increasing frequency, degrees granted by such institutes now accounting for slightly over half the total in natural and technical sciences.

Indeed it is not necessary to be accepted by a graduate school to prepare for the degree of kandidat. The examinations may be taken at will and the research may be pursued independently. It is thus possible to prepare alone and to seek a thesis supervisor when one's research project is already well along, for instance after publication of some significant results.

This "extension" graduate study scheme is frequently used by the younger teaching staff of provincial institutions of higher learning to obtain higher rank and pay and to improve their future prospects. Two examples of this were seen at the Mathematics Chair of the Frunze Polytechnic Institute. With support from their department head, these instructors completed their examinations while working, and did some research which was found worthy of being the basis of a thesis. Once a thesis supervisor is found, the degree-seeker is entitled to a full year's leave with pay in order to complete his research and prepare for defense of the thesis. His expenses are covered by his home school before he has been accepted by a supervisor, by the supervisor's school afterwards. After the defense of the thesis, the recipient of the kandidat degree is committed to return to his original school.

Similar schemes are used ever more frequently at research institutes, where the brightest staff members often prepare themselves for advanced degrees and have great opportunities for conducting research partly in connection with their normal assignment.

Thus, in summary, the degree of kandidat is awarded primarily for a research thesis; and the quality of the degree depends on the quality of the research. On the basis of the rather small sample seen by the Delegation it may be unwise to hazard a guess, but apparently, the analytical (particularly mathematical) theses examined were comparable to American doctoral dissertations.

The Doctor's Degree

The Soviet doctor's degree represents a much higher level of attainment. In order to apply for it, one needs a kandidat's degree; there is no formal requirement except the defense of a research thesis which makes important contributions to knowledge or technology. Altogether, some 600 doctor's degrees were awarded in the USSR in 1958, of which some 130 were in engineering.

When a kandidat feels ready to defend a doctor's thesis, he submits a petition to one of the 147 schools (48 in engineering) or 136 research

institutes (52 in engineering) entitled to hear doctoral dissertation defenses (Appendix F). If the preliminary examination of his work (which is generally well-known and must be published) warrants it, a public defense is scheduled. Again thesis summaries are sent out to 150 experts one month in advance. An announcement of the forthcoming defense is published in the press. Three official opponents are appointed, two of whom must hold doctor's degrees. The defense before the Academic Council and the public then takes place. After presentation, questions and discussion, the Academic Council votes; it does not have power to grant the degree; but by a secret two thirds majority of a two thirds quorum, it may recommend to VAK that the degree be issued.

The Higher Attestation Commission sends the thesis to an expert committee for evaluation; the report of that committee is then discussed by a plenary session of the full Commission and voted on by secret ballot. If the vote is favorable, the degree is granted by VAK. If not, the candidate is called in to defend his work both before the expert committee and VAK itself.

In general, the people who are awarded doctor's degrees are in their late thirties or early forties and well established scientists; they apply for the degree some five or six years after their kandidat's degree; but there have been a few cases of kandidats' theses so outstanding that the academic council involved proposed the thesis for a doctor's degree at the very time it awarded it the kandidat's degree and both degrees were approved by VAK simultaneously.

In many cases known to this delegation, the doctoral thesis has consisted of a loosely connected series of articles published by the aspirant over several years, and there is a strong suspicion that if a scholar is active in publishing reasonably competent material, the doctor's degree comes as a consequence almost as a matter of course. It and the rewards it brings (higher income, professorships, etc. . . .) are the result of keeping scientifically active.

In summary, the Soviet graduate study program appears more similar to the European program than to ours; it almost completely by-passes course work and concentrates on research carried out apprentice-like under a recognized scholar.

IX. RESEARCH

It can be said without reservation that research by the staff is considered an obligation at least equal to that of undergraduate teaching in both the VTUZ's and the universities. Certain facts emphasize the dominant role of research in the whole educational plan. The faculty loads are arranged so that at least 50% and at some institutions as high as 60%, of staff time is devoted to research. On the other hand, no senior member of the staff of a VTUZ devotes 100% of his time to research. People who wish to devote all their time to research have positions with the research institutes of the academies of science or industrial ministries rather than with the engineering schools. On the other hand, those who wish to devote 100% of their time to teaching are not employed in institutions of higher learning except in certain service departments.

In addition to the staff emphasis on research, most of the VTUZ's have

a systematic plan of identifying the better students, usually sometime in the third year of undergraduate study. Such students are encouraged to become interested in research and if they are capable may be given a research project under the supervision of one of the members of the staff. This research project may be used for the diploma project instead of the more usual design type of diploma project.

It is most pertinent to point out that much of the applied and developmental type research which is done in industrial laboratories and in research centers in the United States is done at engineering institutions in the USSR. As a matter of fact, professors of engineering are discouraged from devoting their full research time to basic problems. This is done in the most effective way possible by the incentive of salary, as will be noted in the section below on research support. Even professors on the staffs of universities are encouraged to work closely with industry in their research projects.

The academies of science, on the other hand, devote more of their time to the really basic research problems. This is important to note in connection with engineering education, since a large portion of the kandidat's degrees and doctor's degrees are obtained through the research institutes of the academies of science and industrial ministries rather than through the engineering institutions and universities.

There appear to be three principal types of research operation:

1) The state budget for the institution provides funds for the exploratory theoretical research of the staff. This apparently is similar to the kind of research which is done in the United States in engineering institutions. It involves the study of basic principles in the various engineering sciences and, as far as could be seen, is perfectly comparable with the kind of research, both in quality and variety, that would be conducted in the United States.

2) The contract research program is encouraged by permitting a staff member to earn up to 50% of his base salary through contract research. Thus a staff member would have to be content with a salary of 5,000 rubles per month instead of 7,500 rubles per month if he devoted all of his time to purely State-supported basic research and none of his time to industry-supported contract research. The exception to this would be the case of a professor who would have a part-time (up to 50%) connection with an academy of science. By this arrangement the staff member could earn the limit allowed and still do only basic research. The great majority of the engineering professors encountered by this mission were engaged in contract research up to the point where they were earning 50% additional salary from it. Only professors of service areas, such as chemistry, physics, and mathematics, had part-time connections with academies of science in lieu of research contracts.

The staffs of the research institutes seem to be composed about equally of persons who have obtained their diploma from a VTUZ or from a university. There is, however, little or no distinction in the type of research assignments given them in relation to their engineering or university background. In brief, then, graduate education seems to be divided among the universities, the engineering institutions (VTUZ's), the research institutes, and the industrial ministries. However, by virtue of a ruling of VAK the staff members of engineering institutions may not do research which is concerned with pure science and

members of the staff of universities may not do research which is concerned with applied science. If the academic councils of the individual institutions cannot decide whether a particular research project is an "applied" or "pure" problem, then VAK makes the decision, which is final.

The contracts are between the appropriate industry and the institute. The professor makes the contacts, agrees with the industry on what he wishes to do technically and then the contract is arranged. Most institutes have an assistant director of research who is responsible for negotiating and supervising such contract research. The research contracts usually include the following costs:

(a) Salaries. Included in salaries is an appropriate amount for the time of the professor who is supervising the work plus that of the assistants, technicians, and other personnel. Technicians and assistants may be employed full time on the research.

(b) Costs of any travel in connection with the research.

(c) Expendable materials and supplies.

(d) Equipment which reverts to the institution when the research is completed. As a matter of actual fact, this is one of the major ways institutes have for getting specialized capital equipment.

(e) Indirect costs to take care of costs of the institute not otherwise delineated. The indirect cost varies between 45 and 50% of salaries at most institutes that were checked. This, however, is not a fixed amount which is set by the government as it is in the United States, but is left to each individual institute to negotiate on each individual contract.

In most institutions the indirect costs are placed in a special fund which the director uses in consultation with a faculty committee for the best interests of the institution. In several cases it was pointed out that this fund is used to buy special equipment, outfit additional laboratories, expand laboratories, but is seldom if ever used for support of additional people. Funds for these can be obtained whenever needed from the State budget. The fund might be used occasionally to get someone started, but not to put someone permanently on the budget of the institution.

3) The third type of research which is just coming into being, is the development of special laboratories for an area of research which may begin at a fundamental level and then may be carried to a more practical level if successful results are obtained. For example, at the Kalinin Polytechnic Institute in Leningrad there has been established a special laboratory to study metals of high purity. It was said that there were two major reasons for establishing such separate laboratories. First, by reason of a separate budget, equipment and facilities could be obtained which were specifically designed for research programs which are planned to continue over a period of years. Second, industry would agree to support these laboratories by contract over a period of several years starting at a much more fundamental basis than is the case in the regular contract research.

The amount of contract research compared to research supported by the State varied in the ten institutions checked from 40% contract and 60% budget research to 60% budget research and 40% contract research.

The special laboratory type of research is rather new and the budget amount at the present time cannot be said to bear any particular relationship to the other two. At the Kalinin Polytechnic Institute the budget for

special laboratory type of research, including the pure metals laboratory mentioned above, was three or four million rubles per year, whereas the contract research at the same institute was about 22 million rubles per year. The total budget of the institute itself from the State was 120 million rubles a year. The State budget includes not only the operation of the institution but the salaries of the staff and the grants of an average of 400 rubles per month or 4,800 rubles per year for over 8,000 diploma students. The grants to the students thus account for more than 30% of the State budget.

Contract research is the kind which would be considered in the United States as developmental or applied research, and thus from 50 to 60% of the amount of research which is being done at the engineering schools would be put in that classification. Typical examples of such problems are:

(1) Development of equipment for quality control in ball bearings which involved measuring the sphericity and size of the ball bearing. The original pilot plant equipment was built in the shops of the engineering school and then the prototype was used for student instruction thereafter.

(2) Development of a remote control system for the operation of overhead cranes.

(3) Improvement in the equipment for canning vegetables.

(4) Improvement in agricultural machinery.

Research at the academy of science institutes is assigned according to a general classification of fields in which they may work. Therefore a graduate student who is an aspirant for a kandidat's degree must work for his research in the area in which the institute may operate. As far as could be seen, the true freewheeling research in which a man worked in any area which he liked was limited to relatively few people who had already acquired a reputation as effective research workers. This can be illustrated by the fact that the Academy of Science Institute of Chemistry named for Karpov in Moscow has the following departments: (1) kinetics and mechanisms of catalyzed reactions, (2) kinetics and mechanisms of polymerization, (3) structure and properties of polymers, (4) structure of molecules and crystals, (5) laboratories for electrochemistry, (6) electrochemical processes, (7) separation of mixtures including isotopes, (8) radiation chemistry.

All the research of the institute must fit within these eight departments. The institute has a director and two deputy directors for research, with a total of 900 employees, 250 of whom are professional research workers. Of these professional research workers, 75 have the kandidat's degree. Two of the doctors are members of the Academy and five are corresponding members of the Academy. The majority of the professional workers who do not already have their doctor's or kandidat's degrees are pursuing graduate work, either at the Academy itself or at the university or engineering school from which they graduated, and can therefore be classified as part-time graduate students. In addition, this institute admits each year 15 to 20 full-time graduate students on full grants to pursue research towards the kandidat's degree. These grants are for three-year periods. Thus, there are in residence at all times from 45 to 60 full-time students performing research.

The research in which these graduate students are involved could often be classified as being either in the engineering area or in the basic science area. Of those that were checked,

about one-third could be classified either way depending on the viewpoint. There is no attempt in the institutes of the academies of science to distinguish between the engineering sciences and the basic sciences. However, in the engineering schools and in the universities, the distinction is specified by the Ministry of Education in the charter.

X. APPARENT TRENDS IN SOVIET ENGINEERING EDUCATION

Observations of the exchange mission and statements made by officials of the Ministry of Higher Education and in the Soviet press indicate that significant changes are in prospect for the Soviet educational system as it pertains to the training of engineers.

Secondary education at present centers around the ten-year school, which provides most of the applicants for institutions of higher learning. A small proportion of students enter technicums after only seven years of secondary education. Up to 5% of these graduates may apply for college level work. The ten-year school, in spite of minor changes in 1954–57 which increased the proportion of skill subjects in the curriculum, has remained essentially a college preparatory course. It has been graduating somewhat over a million youngsters a year since 1954, all of them pointed toward higher education both by training and by great social pressure. Of these, only some 200,000 to 250,000 were admitted to institutions of higher learning. The resulting number of secondary school graduates who thereby do not have an opportunity for higher education is the cause of great concern. It is proposed that the number of students who may enter the institutions of higher learning be increased. At the same time, it is anticipated that the rate of attrition will be higher in the first year with intensified competition for higher education at a more advanced level.

It is recognized that there is a need for strengthening the secondary schools and achieving better coordination with schools of higher education. There is being considered, accordingly, a curriculum of eight years common to all students and not significantly different from the previous pattern, followed by three years of specialized secondary training and some work experience, which would be primarily professional, vocational or artistic, depending on the abilities and interests of the students.

Along with the reorganization of the secondary schools following the lines outlined above, which was approved in December, 1958, by the Supreme Soviet of the Communist Party of the USSR, and which will go into effect in the fall of 1959, there is a review of the admission policy to institutions of higher learning. If the secondary schooling is to be more specialized, greater attention will have to be paid to performance of the applicant in his specialty, either by weighting that grade more heavily or by having more specialized examinations. The preference for applicants with two years' experience will be retained and strengthed, at least in engineering, though it will be dropped in mathematics and the natural sciences.

The engineering curriculum is to be revised. In particular, it is felt that the present three-stage, four-to-six-month, practical working period is not satisfactory for intimately acquainting prospective engineers with the workings of industry, partly because it does not allow enough time and partly because it is so chopped up

that the student develops no skill at one position before he is moved to the next, and industry feels that he requires too much attention and produces too little.

The new scheme would call for a period of work of one year; this could either come by splitting the first two years between work and study, either on a six month of each basis or on a half day of each basis, or, for more analytical fields such as aeronautical or electronic engineering, a year of work would be inserted after the fourth, fifth, or sixth semester; that plan was the one favored by all the leading schools, while the plan of having work in the first year was generally preferred by other schools. In any case such a plan would be put into effect next fall with several options, depending either on the school or even on the faculty.

There is considerable reason to agree that most of the industrial practice as carried on at present serves little useful purpose, and in a country short of machinery, some familiarization program appears desirable for most engineers; it is likely that one continuous long period is more effective. In the Soviet environment, with stipends and the pressure for an advanced degree, good prospects will not be easily seduced away from further schooling, and industry will get more useful labor support from the program and will therefore cooperate more effectively.

There is some danger that these reorganizations of high school, admissions and practice period will increase the specialization by starting it earlier and by tying the schools more closely to their associated industries, and that engineering research and the more analytical parts of engineering will be somewhat slighted.

Another important factor concerns enrollment. If high school is lengthened by a year and engineering school is lengthened by six months to a year, this may involve the loss of two "classes" of engineers or 160,000 of them at the present rate. Such a gap would seriously interfere with long-range planning; to avoid it and smooth over transition to the new system, the rate of admission is likely to increase sharply for the next few years, possibly to the extent of doubling. Supplementing this, by 1964 the number of persons becoming 18 years of age is expected to increase appreciably. These factors would have the effect of minimizing the disturbance in graduating rates and economic planning due to the new reforms and would permit experimentation with another scheme, which is also designed to decrease the psychological effect of failure to gain admission.

According to First Deputy Minister of Higher Education V. N. Stoltetov, this might introduce a new admissions policy with a permanently higher number of admissions and a thorough weeding out over the first two years; the strain of such a policy on the present teaching staff is clear; the advantage of a larger proportion of high school graduates getting a chance at college before being excluded is clear also.

It does not appear, however, that the chances discussed above, significant though they are, will change the broad pattern of Soviet education in engineering. Nor will they affect the goals of the seven-year plan in education which calls for a continuous steady increase in enrollment to a total of 2,300,000 by 1965, of whom 850,000 will be in engineering.

The growth of the system is to be particularly large in the schools in the eastern regions (for example, the Frunze Polytechnic Institute will grow from a present enrollment of 1,400 daytime and 400 evening students to

2,500 daytime and 600 evening students). Another area likely to expand is the extension program, which is already growing very rapidly (All Union Moscow Extension Polytechnic Institute went from 19,000 in 1955 to 36,000 in 1958). Apparently, the long-established schools are not expected to grow appreciably.

Nor is the growth to be uniform in all fields of engineering. Two areas due for expansion are stated to be chemical engineering and electronic engineering, while the classical machine construction curricula may be in for slight retrenchments. At the same time, entirely new curricula and specialties are making their appearance: for example, atomic power station design at the Moscow Power Institute, or missile and satellite design at the Physics Technical Institute in Moscow, a new school whose four departments are listed as radio physics, radio technology, aero-mechanics and physical chemistry.

In summary, the Soviets feel that their supply of engineers has fairly well caught up with present and expected needs, and they are now readjusting the machinery for a situation of slower growth and near balance between the supply and demand for technical personnel. At present, plans are no longer limited by a shortage of engineers, and therefore, some thought can be given to limiting the frustration and maladjustment among young people due to imbalance between secondary and higher education.

They are adjusting their system to changes in technology by shifting emphasis in development plans and letting leading schools experiment with new curricula. They have for the last 12 years struggled with the problem of excessive specialization, with moderate success so far as course subject matter is concerned, but with very little success so far as breadth of outlook is concerned. At the 14 experimental schools a definite trend was observed toward broadening of curricula. This was particularly noticeable in the uniformity of the course content in the first 2 or 3 years.

APPENDICES

Appendix A

Itinerary of Engineering Education Mission to the USSR

Nov. 11	Arrival in Moscow from Copenhagen via Stockholm	Entire delegation
Nov. 12 a.m.	Ministry of Higher Education (Deputy Minister Rumiantsev)	Entire delegation
Nov. 12 p.m. 13 all day	Moscow Power Institute (MEI)	Entire delegation
Nov. 14 all day 15 all day	Moscow Bauman Higher Technical School (MVTU)	Entire delegation
Nov. 16–17	Travel to Kuibyshev	Entire delegation
Nov. 18	Kuibyshev Industrial Institute	(Alexander, Everitt, Fadum, Guy, Lindvall, Morgen)
Nov. 18	Kuibyshev Aviation Institute	(Hall, Trilling)
Nov. 18 (eve)	Kuibyshev Dam and Power Station	Entire delegation
Nov. 19	Travel to Tashkent	Entire delegation
Nov. 20	Travel to Frunze	Entire delegation
Nov. 21 a.m. p.m.	Frunze Polytechnic Institute Academy of Sciences of Kirgiz SSR	Entire delegation Entire delegation
Nov. 22 a.m.	Frunze Polytechnic Institute	(Everitt, Hall, Guy, Lindvall, Morgen, Trilling)
	Frunze Projects Institute and Frunze Irrigation Technicum	(Alexander, Fadum)
p.m.	Kirgiz State University	Entire delegation
Nov. 23	Travel to Moscow Travel to Leningrad	(Hall, Trilling) Rest of delegation
Nov. 24	Leningrad Polytechnic Institute	(Alexander, Everitt, Fadum, Guy, Lindvall, Morgen)
	All-Union Extension Polytechnic Institute	(Hall, Trilling)
Nov. 25	Leningrad Electro-Technical Institute	(Everitt)
	Leningrad Lensoviet Technological Institute	(Guy, Morgen)
	Leningrad Railroad Engineering Technical Institute	(Alexander, Fadum, Lindvall)
Nov. 25–26	Moscow Aviation Institute	(Hall, Trilling) (Also on Nov. 26 Everitt, Lindvall)
Nov. 26–27	Moscow Construction Institute	(Alexander, Fadum)
	Moscow Mendeleev Chemical Technology Institute	(Guy, Morgen)
Nov. 27	Moscow Electrical Communications Institute	(Everitt, Lindvall)

Appendix A (continued)

	Moscow State University (Physics faculty)	(Hall, Trilling)
Nov. 28	Karpov Physical Chemistry Research Institute of the Academy of Sciences	(Morgen)
Nov. 28–29	Baikov Metallurgical Institute of the Academy of Sciences	(Guy)
	Research Institutes of the Architecture Academy	(Alexander, Fadum)
Nov. 28	Steklov Mathematical Institute of the Academy of Sciences	(Hall, Trilling)
Nov. 29	Ministry of Higher Education:	
	Polytechnic Division	(Hall, Lindvall)
	Methods and Pedagogic Division	(Everitt)
	Planning and Placement Division	(Morgen, Trilling)
Nov. 30	Rest and sight-seeing	Entire delegation
Dec. 1	Higher Attestation Commission (VAK)	Entire delegation
	Ministry of Higher Education (1st Deputy Minister Stoletov)	Entire delegation
Dec. 2	Departure from Moscow for Stockholm	Entire delegation

Appendix B

Organization of Ministry of Higher Education

Vysshaia shkola (Append. J) p. 18—6/6—1956 Decree

1. Main administration of universities, economic and legal higher schools.
   a. Administration of Universities
   b. Administration of Economic Schools
   c. Administration of Law Schools
2. Main administration of polytechnic and machine construction institutes.
   a. Administration of Polytechnic Schools
   b. Administration of Machine Construction Schools
3. Main administration of mining, metallurgical and civil engineering construction institutes.
   a. Administration of Mining and Metallurgical Schools
   b. Administration of Construction Schools
4. Main administration of technological (chemical) institutes.
   a. Administration of Chemical Technology Institutes
   b. Administration of Food Industry Institutes
   c. Administration of Light Industry Institutes
5. Main administration of budgeted expendable materials and equipment.
6. Main administration of capital construction.
7. Administration of social science teaching.
8. Administration of middle technical schools.
9. Administration of methodology.
10. Staff administration.
11. Division of physical preparation.
12. Division of planning and placement of young specialists.
13. Division of foreign relations.
14. Financial planning division.
15. First division.
16. Second division.
17. Central book-keeping office.
18. Inspection office.
19. Secretariat.
20. Purchasing office.

Appendix C

Specialties Offered by Soviet Higher Institutions of Learning in Science and Technology *

I. *Geology and Exploration of Mineral Deposits*

1. Geology and exploration of mineral deposits
2. Geology and exploration of oil and gas reserves
3. Exploration and preparation of peat deposits for exploitation
4. Geophysical methods of prospecting for and exploration of mineral deposits
5. Hydro-geology and engineering geology
6. Technics of exploring mineral deposits

II. *Exploitation of Mineral Deposits*

1. Mine surveying (Markscheider method)
2. Exploitation of mineral deposits
3. Exploitation of peat deposits
4. Sorting and refining of mineral ores
5. Exploitation of oil and gas reserves
6. Construction of mining enterprises

III. *Power*

1. Electric power stations, networks, and systems
2. Technology of high tension
3. Electrification of industrial enterprises and installations
4. Mining electro-mechanics
5. Heat power installations for electric power stations
6. Water and fuel technology of electric power stations and industrial installations
7. Water power installations
8. Industrial heat power
9. Physics of heat

IV. *Metallurgy*

1. Metallurgy of ferrous metals
2. Metallurgy of non-ferrous metals
3. Metallurgical furnaces
4. Foundry production of ferrous and non-ferrous metals
5. Physical-chemical research of metallurgical processes
6. Physics of metals
7. Metal technology, equipment, and technology of thermal treatment of metals
8. Hot and cold working of metals

V. *Machine Building and Instrument Construction*

1. Technology of machine building, metal-cutting tools and instruments
2. Machinery and technology of foundry production
3. Machinery and technology of hot and cold working of metals
4. Equipment and technology of welding processes
5. Mechanical equipment of ferrous and non-ferrous metallurgical plants
6. Mining machinery
7. Peat-extraction machinery
8. Machinery and equipment for oil and gas extraction
9. Agricultural machinery
10. Elevator-transport machinery and equipment
11. Construction and road machinery and equipment
12. Railway car construction
13. Automobiles and tractors
14. Shipbuilding and ship repair
15. Printing machinery
16. Machinery and instruments of chemical production
17. Machinery and instruments of food production
18. Machinery and instruments of light and textile industry production
19. Machinery and mechanisms of timber industry and wood production
20. Boiler construction
21. Turbine construction
22. Internal combustion engines
23. Marine engines and mechanisms

* By decree of the U.S.S.R. Minister of Higher Education on September 9, 1954, as amended up to June, 1957, omitting non-engineering specialties offered only at universities and non-technical institutions.

Appendix C (continued)

24. Ship power installations
25. Locomotive construction
26. Hydraulic turbines and other hydraulic machines
27. Refrigeration and compressor machines and plants
28. Optical instruments
29. Tools of precision mechanics
30. Geodesic instruments
31. Cinematographic instruments

VI. *Electrical Machine Construction and Electrical Instrument Construction*

1. Electrical machinery and instruments
2. Electrical transport
3. Electrical insulation and cable technology
4. Dielectrics and semi-conductors
5. Electric vacuum machines
6. Automatic, remote control, and electrical measuring instruments and systems
7. Instruments for directing and controlling chemical production
8. Mathematical and computing instruments and systems
9. Gyroscopic instruments and mechanisms
10. Electrical acoustics
11. Electronic instruments
12. Industrial electronics
13. Electro-thermal installations
14. Illumination and projector construction
15. Acoustics

VII. *Radio Engineering and Communications*

1. Radio engineering
2. Telegraphic and telephonic communications
3. Construction design and technology of producing radio equipment

VIII. *Chemical Technology*

1. Technology of oil and gas
2. Chemical technology of fuel
3. Technology of non-organic substances
4. Technology of rare and diffused elements
5. Technology of electro-chemical production
6. Technology of silicates
7. Technology of basic organic synthetics and of synthetic rubber
8. Technology of dyes and by-products
9. Technology of medicinal and aromatic substances
10. Technology of plastics
11. Technology of lacquers, paints, and non-metallic coatings
12. Technology of rubber
13. Technology of cinematographic-photographic materials

IX. *Forest Engineering and Technology of Wood, Cellulose, and Paper*

1. Forest engineering
2. Mechanical technology of wood
3. Chemical technology of wood
4. Technology of cellulose-paper production

X. *Technology of Food Products*

1. Storage and technology of processing grain
2. Technology of bread-baking, macaroni, and confectionery production
3. Technology of sugar substances
4. Technology of fermentative products
5. Technology of wine-making
6. Technology of vegetable fats
7. Technology of food preservation
8. Technology of subtropical culture
9. Technology of meat and milk products
10. Technology of fish products
11. Equipment and technology of public catering
12. Industrial fisheries
13. Ichthyology and fish breeding

XI. *Technology of Consumers' Goods*

1. Primary treatment of fibrous materials
2. Mechanical technology of fibrous materials
3. Chemical technology of fibrous materials
4. Technology of artificial fabrics
5. Technology of sewing industry
6. Technology of leather and fur
7. Technology of artificial leather
8. Technology of manufactured leather goods
9. Technology of printing industry

Appendix C (continued)

XII. *Construction*

1. Architecture
2. Industrial and civil construction
3. Hydrotechnical construction of river installations and hydroelectric stations
4. Hydrotechnical construction of maritime waterways and ports
5. Agricultural construction
6. City construction and economy
7. Production of concrete and ferroconcrete materials and of constructions for assembled buildings
8. Gas heat supply and ventilation
9. Water supply and canalization
10. Railroad construction
11. Automobile roads
12. Bridges and tunnels

XIII. *Geodesy and Cartography*

1. Engineering geodesy
2. Astronomo-geodesy
3. Air photographic geodesy
4. Cartography

XIV. *Hydrology and Meteorology*

1. Hydrology of land
2. Oceanography
3. Hydrography
4. Meteorology
5. Agricultural meteorology

XV. *Rural and Forest Economy*

1. Soil science and agricultural chemistry
2. Agronomy
3. Fruit, vegetable, and grape growing
4. Plant protection
5. Sericulture
6. Zootechnology
7. Veterinary science
8. Land utilization managements
9. Mechanization of agricultural production processes
10. Electrification of agricultural production processes
11. Irrigation
12. Forest economy

XVI. *Transportation (Development)*

1. Rolling stock and traction economy of railroad transport
2. Electrification of railroad transport
3. Automation and remote control processes and communications in railroad transport
4. Development of railroad transport
5. Municipal electrified transportation
6. Maritime shipping
7. Internal waterways shipping
8. Development of water transport
9. Development of automobile transport
10. Development of aircraft and motors

XVII. *Economics*

1. Planning of national economy
2. Economics of production
3. Economics and planning of material-technical supply
4. Economics of labor
5. Economics and organization of mining industry
6. Economics and organization of oil and gas industry
7. Economics and organization of power
8. Economics and organization of metallurgical industry
9. Economics and organization of machine building industry
10. Economics and organization of ship building industry
11. Economics and organization of chemical industry
12. Economics and organization of printing industry
13. Economics of cinematography
14. Economics and organization of consumers' goods industry
15. Economics and organization of agriculture (agronomist-economist requiring 5 years of study)
16. Economics of agriculture (economist requiring 4 years of study)
17. Economics and organization of agricultural products supply
18. Economics and organization of food products industry
19. Economics and organization of forest economy and timber production
20. Economics and organization of wood-processing and cellulose-paper industry

Appendix C (continued)

21. Economics and organization of construction
22. Economics and organization of municipal economy
23. Economics and organization of railroad transport
24. Economics and organization of water transport
25. Economics and organization of automobile transport
26. Economics and organization of air transport
27. Economics and organization of communication
28. Economics of trade
29. Economics of public catering
30. Economics of foreign trade
31. Principles of merchandising industrial goods
32. Principles of merchandising food products
33. Finance and credit
34. International monetary-financial relations
35. Statistics
36. Accounting system
37. Mechanization of accounting and calculator work

Appendix D

Classification of Soviet Engineering Schools (VTUZ's)

Source—*Spravochnik—1958* (Append. J)

Type of School	Number
1. †Polytechnic Institutes	29
2. †Power Institutes	3
3. †Electro-Technical Institutes	2
4. Radio-Technical Institutes	2
5. †Machine Construction Institutes	19
6. Shipbuilding Institutes	2
7. †Aviation Institutes	7
8. Polygraphic Institutes	3
9. Motion Picture Engineering Institutes	1
10. Geological, Prospecting and Mining Institutes	11
11. Petroleum, Coal and Peat Institutes	4
12. †Metallurgical Institutes	12
13. †Chemical Technology Institutes	10
14. Food Technology Institutes	9
15. Fish Industry Institutes	4
16. Light Industry Institutes	3
17. Textile Institutes	5
18. †Civil Engineering and Construction Institutes	20
19. Geodesic Institutes	2
20. Automobile Highway Institutes	7
21. Hydro-Meteorological Institutes	2
22. †Railroad Transport Engineering Institutes	14
23. Water Transport Engineering Institutes	4
24. Sea Transport Engineering Institutes	4
25. Civil Air Transport Institute	1
26. †Communications Institutes	7
27. *Agricultural Institutes	67
28. Military Engineering Institutes Air Engineering Academies Artillery Academy Tank School	3

* These are not engineering schools but have agricultural machinery faculties. They are not included in the total of engineering schools.

† This type of school was visited by the delegation.

Appendix E

Institutions Having Outstanding Engineering Programs

A. *Leading Higher Technical Education Institutions (VTUZ's)*

*1. Moscow Higher Technical School (Baumann)
*2. Moscow Power Institute
*3. Moscow Aviation Institute
*4. Leningrad Polytechnic Institute
*5. Leningrad Precision Mechanics & Optics Institute
*6. Leningrad Shipbuilding Institute
*7. Leningrad Electrotechnical Institute
*8. Moscow Mendeleev Chemical Technology Institute
9. Kuibyshev Construction Institute
10. Moscow Stalin Steel Institute
11. Moscow Physics Technical Institute
12. Moscow Engineering Physics Institute
13. Ural Polytechnic Institute
14. Kiev Polytechnic Institute
15. Kharkov Polytechnic Institute
16. Tomsk Polytechnic Institute

B. *Technical Institutions of Higher Learning with 5 1/2 Year Curriculum*

Vysshaya Shkola—1957—p. 61 (Append. J)

*1. Moscow Higher Technical School (Baumann Institute)
*2. Moscow Power Institute
*3. Moscow Aviation Institute
*4. Leningrad Polytechnic Institute
5. Leningrad Precision Mechanics and Optics Institute
6. Leningrad Shipbuilding Institute
7. Leningrad Aircraft Equipment Institute
8. Leningrad Military Mechanical Institute
9. Moscow Engineering Physics Institute
10. Nikolaev Shipbuilding Institute
11. Kazan Aviation Institute
*12. Kuibyshev Aviation Institute
13. Kharkov Aviation Institute
*14. Leningrad Electrotechnical Institute

It is not clear that this list (B) is correct for schools entitled to introduce new courses because, since certain second level schools are included; the list also has no civil (construction), metallurgical or chemical engineering representatives.

C. *Shipbuilding, Engineering Physics, and Physical Chemistry Faculties with 5 1/2 Year Curriculum*

Vysshaya Shkola—1957—p. 62 (Append. J)

1. Gorki Polytechnic Institute	Shipbuilding
2. Far Eastern Polytechnic Institute (Vladivostok)	Shipbuilding
3. Tallinn Polytechnic Institute	Shipbuilding
4. Gorki Water Transport Engineers' Institute	River-boat Building
5. Leningrad Water Transport Engineers' Institute	River-boat Building
6. Odessa Merchant Marine Institute	River-boat Building
*7. Moscow Mendeleev Chemical Technology Institute	Physical Chemistry

* Designates schools visited.

Appendix E (continued)

8. Moscow Stalin Steel Institute	Physical Chemistry
9. Moscow Non-Ferrous Metals Institute	Engineering Physics
10. Ural Polytechnic Institute (Sverdlovsk)	Engineering Physics
11. Kiev Polytechnic Institute	Engineering Physics
12. Kharkov Polytechnic Institute	Engineering Physics

Appendix F

List of Higher Educational Institutions and Scientific Research Institutes Entitled to Admit Students for the Defense of Doctors' and Kandidats' Dissertations, and to Certify Students for the Degree of Doctor of Science, and to Grant, on the Basis of Thesis Defense, the Degree of Kandidat of Science

Ministry of Higher Education

1. Azerbaijan State University
2. Byelorussian State University
3. Vilnius State University
4. Voronezh State University
5. Dniepropetrovsk State University
6. Erivan State University
7. Kazan State University
8. Kazakh State University
9. Latvian State University
10. Leningrad State University
11. Moscow State University
12. Rostov-on-the-Don State University
13. Saratov State University
14. Central Asiatic State University
15. Tartu State University
16. Tbilisi State University
17. Tomsk State University
18. First Moscow State Pegagogical Institute of Foreign Languages
19. Moscow State Institute of Economics

*20. Moscow Institute of Engineering and Economics

*21. Leningrad Institute of Engineering and Economics

22. Leningrad Institute of Finances and Economics
23. Moscow Institute of Finances

*24. Azerbaijan Polytechnical Institute

*25. Georgian Polytechnical Institute (Tbilisi)

*26. Leningrad Polytechnical Institute

*27. Central Asiatic Polytechnical Institute (Tashkent)

*28. Tomsk Polytechnical Institute

*29. Ural Polytechnical Institute (Sverdlovsk)

*30. Leningrad Electro-technical Institute

*31. Leningrad Institute of Precision Mechanics and Optics

*32. Moscow Power Institute

*33. Moscow Higher Technical School (MVTU-Bauman Institute)

*34. Moscow Institute of Machine-Tools

*35. Moscow Institute of Physical Engineering and Physics

*36. Leningrad Shipbuilding Institute

*37. Leningrad Mechanics Institute

*38. Moscow Institute of Auto-mechanics

*39. Moscow Aviation Institute

*40. Kazan Aviation Institute

*41. Leningrad Mining Institute

*42. Moscow Geological Surveying Institute

*43. Moscow Mining Institute

*44. Moscow Oil Institute

*45. Sverdlovsk Mining Institute

*46. Moscow Peat Institute

*47. Moscow Institute of Non-ferrous Metals and Gold

*48. Moscow Steel Institute

*49. Leningrad Institute of Construction Engineering

*50. Moscow Institute of Construction Engineering

*51. Moscow Institute of Automobile Highways

*52. Moscow Institute of Engineering Geodesy, Aerophoto Surveying and Cartography

*53. Kazan Chemical Technological Institute

* Offers courses in engineering.

Appendix F (continued)

*54. Moscow Institute of Precision Chemical Technology
*55. Moscow Institute of Chemical Machine Construction
*56. Moscow Mendeleev Chemical-Technological Institute
*57. Leningrad Lensoviet Technological Institute
*58. Moscow Technological Institute of the Food Industry
*59. Moscow Technological Institute of the Meat and Dairy Industry
*60. Leningrad Technological Institute of the Refrigeration Industry
61. Leningrad Forestry Academy
62. Moscow Forestry Institute
*63. Moscow Technological Institute of Light Industry
*64. Moscow Textile Institute
*65. Moscow Architectural Institute

Ministry of Agriculture USSR

66. Voronezh Agricultural Institute
67. Latvian Agricultural Academy
68. Leningrad Agricultural Institute
69. Omsk Agricultural Institute
70. Tashkent Agricultural Institute
71. Moscow Institute of Land Exploitation Engineers
*72. Moscow Institute for the Mechanization and Electrification of Agriculture
73. Alma-Ata Zooveterinarian Institute
74. Erivan Zooveterinarian Institute
75. Kazan Veterinarian Institute
76. Leningrad Veterinarian Institute
77. Moscow Veterinarian Institute
78. Omsk Veterinarian Institute
79. Moscow Institute of Water Economy
80. Georgian Agricultural Institute
81. Moscow Timiriazev Agricultural Academy
82. Ukraine Agricultural Academy
83. Kharkov Agricultural Institute
84. Kharkov Veterinarian Institute
85. Kiev Veterinarian Institute
86. All-Soviet Scientific-research Institute of Cattle Breeding VASKhNIL
87. All-Soviet Institute of Experimental Veterinary Science
88. All-Soviet Scientific-research Institute of Plant-Growing
89. All-Soviet Institute of Helminthology (worm parasites)
90. All-Soviet Scientific-research Institute of Fodder

Ministry of Agriculture USSR

91. Byelorussian Scientific-research Institute of Land Exploitation

Ministry of Higher Education Ukraine SSR

92. Kiev State University
93. Lvov State University
94. Odessa State University
95. Kharkov State University
*96. Kiev Polytechnic Institute
*97. Lvov Polytechnic Institute
*98. Kharkov Polytechnic Institute
*99. Dniepropetrovsk Metallurgical Institute
*100. Kiev Technological Institute of the Food Industry
*101. Kiev Engineering-Construction Institute

Academy of Sciences USSR

*102. Institute of Automation and Remote Control
103. Institute of Biochemistry
104. Botanical Institute
105. Institute of Oriental Studies
106. Institute of Genetics
*107. Institute of Mining
108. Institute of Geography
109. Geological Institute
*110. Institute of Solid Fuels
111. Zoological Institute
112. Historical Institute
113. Institute of the History of Art
114. Institute of the History of Material Culture
115. Institute of Russian Literature
116. Steklov Mathematical Institute
*117. Institute of Machine Utilization
*118. Institute of Metallurgy
*119. Institute of Mechanics
120. Institute of World Literature
121. Institute of General and Inorganic Chemistry
122. Institute of Organic Chemistry
123. Soil Institute

* Offers courses in engineering.

Appendix F (continued)

124. Institute of Law
125. Institute of Geo-Chemistry and Analytical Chemistry
126. Institute of High Molecular Formations
127. Institute of Linguistics
128. Unified Council of Institutes of Physics of the Earth, Physics of the Atmosphere, and Applied Geophysics
129. Physics Institute
130. Institute of Physiology
131. Forestry Institute
132. Institute of Plant Psychology
133. Institute of Physical Problems
134. Institute of Physical Chemistry
135. Institute of Philosophy
136. Institute of Chemical Physics
*137. Institute of Radio Technology and Electronics
138. Institute of Microbiology
139. Institute of Economics
*140. Krzhizhanovskii Power Institute
141. Institute of Ethnography
*142. Physico-Technical Institute
143. Paleontology Institute
*144. Radiation Institute
*145. Thermo-Technical Laboratory
*146. Acoustics Institute
*147. Oil Institute
148. Main Astronomical Observatory
149. Institute of Oceanography
150. Institute of Higher Nervous Activity
151. Institute of Crystallography
*152. Institute of Refrigeration
153. United Council of the Ural Branch
*154. Institute of the Chemistry of Silicates
*155. Institute of Precision Mechanics and Computer Techniques
156. Institute of Animal Morphology
157. Institute of the History and Techniques of Natural Science
158. Institute of Organic-Element Formations
159. Institute of Slavonic Affairs
*160. Institute of Complex Transportation Problems
*161. Department of Applied Mathematics of the Steklov Mathematical Institute
*162. Institute of the Geology of Ore Deposits, Petrography, Mineralogy and Geo-Chemistry

Azerbaijan Academy of Sciences

*163. Oil Institute

Armenian Academy of Sciences

164. United Council of Institutes of Language and Literature

Byelorussian Academy of Sciences

*165. Department of Physico-Mathematical and Technical Sciences
166. Institute of Biology

Georgian Academy of Sciences

167. Institute of History
168. Institute of Mathematics
169. Institute of Linguistics

Kazakh Academy of Sciences

170. Institute of Geological Sciences
171. United Council of Institute of Languages and Literatures and Institute of History, Architecture and Ethnography

Kirghiz Academy of Sciences

172. Department of Biological Sciences
173. Institute of Experimental Medicine

Ukraine Academy of Sciences

174. Department of Biological Sciences
175. United Council of the Institute of Physics and Institute of Mathematics
176. United Council of the Institutes of Organic and Inorganic Chemistry
*177. Institute of Structural Mechanics
*178. Department of Social Sciences

Academy of Medical Sciences USSR

179. Council of the Department of Clinical Medicine
180. Council of the Medical-Biological Department
181. Council of the Department of Hygiene, Microbiology and Epedemiology

* Offers courses in engineering.

Appendix F (continued)

182. Institute of Experimental Medicine
183. Institute of Biophysics

Academy of Pedagogical Sciences Russian SSR

184. Scientific-Research Institute for Teaching Methods
185. Institute of Psychology
186. Scientific-Research Institute of Physical Education and School Hygiene
187. Scientific-Research Institute of the Theory and History of Pedagogy

Colleges and Scientific Institutions Central Committee of the Communist Party

188. Higher Party School
189. Institute of Marxism and Leninism
190. Academy of Social Sciences

Ministry of Aircraft Production (secret)

*191. ——
*192. ——
*193. ——

Ministry of Foreign Trade

194. Institute of Foreign Trade

Ministry of Geology and Conservation of Mineral Resources USSR

195. United Council of the Institute for Geological Scientific Research

Ministry of Health USSR

196. Central Institute of Medical Improvement
197. State Scientific-Research Institute for the Study of Microbes and Epidemics of the Southwest

Ministry of Health—Russian SSR

198. State Institute for Improvement of Qualifications of Medical Doctors
199. First Leningrad Medical Institute
200. Central Scientific-Research Roentgen-Radiological Institute
201. Leningrad State Pediatric Institute
202. First Moscow Medical Institute
203. Moscow Institute of Pharmacy
204. Gorky Institute of Medicine
205. Kazan State Institute of Medicine
206. Kuibishev State Medical Institute
207. Leningrad Sanitary-Hygiene Institute
208. Second Moscow State Medical Institute
209. Saratov State Medical Institute
210. Sverdlovsk State Medical Institute
211. Voronezh State Medical Institute
212. Moscow State Stomatological Institute
213. State Scientific Research Institute of Roentgenology and Radiology
214. Riazan Medical Institute
215. Tomsk State Medical Institute

Ministry of Health of Azerbaijan SSR

216. Azerbaijan State Medical Institute

Ministry of Health of Byelorussian SSR

217. Minsk State Medical Institute

Ministry of Health—Armenia

218. Erivan Medical Institute

Ministry of Health—The Ukraine

219. Kiev Medical Institute
220. Kharkov Medical Institute
221. Lvov Medical Institute

Ministry of Health—Kazakh SSR

222. Kazakh Medical Institute

Ministry of Health—Usbek SSR

223. Tashkent Medical Institute

Ministry of Health—Georgia SSR

224. Tbilisi State Medical Institute

Ministry of Health—Latvia SSR

225. Riga Medical Institute

Ministry of Foreign Affairs—USSR

226. Moscow State Institute of International Affairs

Ministry of Culture—USSR

227. Institute of Painting, Sculpture and Architecture
228. Leningrad State Conservatory

* Offers courses in engineering.

Appendix F (continued)

229. State Institute of Theatrical Arts
230. Moscow State Conservatory

Ministry of Communal Economy—Russian SSR

231. Academy of Communal Economy

Ministry of the Navy

*232. Leningrad Higher Naval Engineering Institute

Ministry of Petroleum Production—USSR

*233. All-Soviet Petroleum Scientific-Research Institute
*234. All-Soviet Petroleum Scientific-Research Geological Prospecting Institute (VNITRI)
*235. All-Soviet Institute for Scientific Research in the Geological Prospecting of Petroleum (VNIGNI)

Ministry of Defense Industry and Ministry of Defense

236–261. (27 not named)

Ministry of Enlightenment—Russian SSR

262. Leningrad State Pedagogical Institute
263. Moscow State Pedagogical Institute, named after Potemkin
264. Moscow State Pedagogical Institute, named after Lenin

Ministry of Ways of Communication

*265. Leningrad Institute of Railway Transport
*266. Moscow Institute of Engineers of Railway Transport

Ministry of River Fleets

*267. Gorky Institute of Engineers of River Transport
*268. Leningrad Institute of Engineers of River Transport

Ministry of the Fishing Industry

*269. Moscow Technical Institute of Fish Industry and Economy

Ministry of Radiotechnical Industry

(secret)

*270. ——

Ministry of Communications—USSR

*271. Moscow Electro-Technical Institute of Communications

Ministry of Naval Construction

(secret)

*272. ——

Ministry of Commerce—USSR

273. Moscow Institute of National Economy

Ministry of Heavy Machinery

*274. Central Scientific-Research Institute of Technology and Machine Construction

Ministry of Chemical Industry

*275. Karpov Physical-Chemical Research Institute

Ministry of Power Stations

*276. All-Soviet Scientific-Research Institute of Hydrotechnics

A Main Administration of the Hydro-Meteorological Service of the Council of Ministers of the USSR

*277. Central Institute of Forecasts

State Committee for Construction of the Council of Ministers of the USSR

278. Academy of Construction and Architecture
*279. Central Scientific-Research Institute for Industrial Construction
*280. Scientific-Research Institute of Foundations and Soil Mechanics

State Committee of the Council of Ministers of the Ukraine SSR for Construction and Architecture

*281. Academy of Construction and Architecture

Committee of Standards, Measures and Measuring Apparatus of the Council of Ministers of the USSR

282. All-Soviet Scientific-Research Institute of Meteorology

Ministry of Justice—Russian SSR

283. Institute of Juridical Sciences

* Offers courses in engineering.

Appendix G

Selected Study Plans (Uchebnyie Plany)

A) Electronic Devices (1955/56) (0611)
(a) Five year course (standard)
(b) 5½ year course (Moscow Power Institute)

Subject	Total, hr.		Lecture, hr.		Laboratory, hr.		Recitation, hr.		Hours per week—per semester																					
									I		II		III		IV		V		VI		VII		VIII		IX		X		XI	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Principles of Marxism & Leninism	256	250	156	160			100	90	4	5	3	3	4	3	4	5											↑			↑
Political economy	140	140	100	100			40	40									3	3	2	3	2	3	3	1						
Foreign language	256	252					256	252	2	2	2	2	2	2	2	2	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)						
Higher mathematics	408	410	220	222	16		172	188	8	8	8	7	4	5	4	4														
Physics	306	428	186	206	86	120	34	102	4		7	7	5	8	2	4		6												
Chemistry	120	108	70	54	50	54			4	6	3																			
Descriptive geometry & drafting	210	208	36	36			174	172	7	6	3	2	2	2		2														
Theoretical mechanics	120	170	86	102			34	68			3	5	4	5																
Strength of materials	256	80	156	48	32		*68	32					4		7	5	4													
Metal working & shop	170	204	52	68	118	118		18	5	3	5	6		3																
Electrical circuits	290	254	172	118	84	68	34	68					5	2	8	8	4	5												
Electrotechnical materials	72	48	54	36	18	12														4	4						Diploma Project		Diploma Project	
Electrical measurements	72	114	36	54	36	36		*24									4	5												
Electrical machines	108	132	72	84	36	48											6	2		8										
Electromagnetic fields		72		36		18		18										4												
Electro vacuum technology	132	90	92	54	40	36											4	5	6	2										

Parentheses mean can be taken as an extra load.
* Projects combined with recitation.

Appendix G (A)—Continued

Subject	Total, hr.		Lecture, hr.		Laboratory, hr.		Recitation, hr.		Hours per week—per semester																			
									I		II		III		IV		V		VI		VII		VIII		IX		X		XI	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Radio technology	150	84	102	72	30	12	18										5		6	7										
Electrical effects in gases		84		60		24														7										
Illumination		64		48		16																4								
Electron tubes	156	200	102	120	36	56	*18	*24											3		7	8		6						
Ionic devices	80	48	50	32	30	16													8			3								
Technology of electro vacuum devices	186	172	120	116	46	56	*20										4		2		3	5	4	5		2				
UHF devices	196	160	128	120	40	40	*28														6		6	4	2	4		4		
Photo electric devices		64		48		16																4								
Semi conductors	42	48	28	48	14																	3			3					
Testing & use of electronic devices	104	212	62	148	42	40		*24															2	5	6	5		6		
X-ray devices	102	112	78	88	24	24																	6		3	4		4		
Generation & measure of radiation	84		56		28														3		3									
Economics of electronic industry	100	96	86	68			*14	28															3		5	3		4		
Safety and fire prevention	42	36	32	36	10																			3	3					
History of technology		48		36				12																4						
Pre-diploma electives	70		70																						5					
Typical calculations		244						244		2		2		2		2		4		3										
Research		336				336																4		4		8		8		
Physical education	136	136					136	136	2	2	2	2	2	2	2	2														
Totals	4364	5104	2402	2418	816	1146	1146	1540	36	34	36	36	32	34	29	34	34	34	30	34	25	34	24	32	27	26		26		

Appendix G

B) Turbine Design (1955/56) (0521)—(a) Five year course (standard)
(b) 5½ year course (Moscow Higher Technical School—Bauman Institute)
(Aircraft engine option; other available options are steam and gas turbines)

Subject	Total, hr.		Lecture, hr.		Laboratory, hr.		Recitation, hr.		Hours per week—per semester																					
									I		II		III		IV		V		VI		VII		VIII		IX		X		XI	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Principles of Marxism & Leninism	256	250	156	160			100	90	4	5	3	3	4	3	4	5											↑			
Political economy	140	140	100	100			40	40									3	3	2	3	2	3	3	3						
Foreign language	256	252					256	252	2	2	2	2	2	2	2	2	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)						
Higher mathematics	403	408	220	220	16		172	188	8	8	8	7	4	5	4	4														
Physics	274	274	170	170	70	70	34	34	4		7	6	5	7		4														
Chemistry	104	104	36	36	68	68			4	4	2	2																		
Descriptive geometry & drafting	276	278	54	54			222	222	8	9	4	4	2	2	2	2														
Theoretical mechanics	200	215	134	115			66	100			4	3	4	6	4	6														
Strength of materials	226	232	140	133	34	33	52	66					4	4	4	5	5	6												
Mechanisms & machines	100	197	64	80		20	*36	*97							4	4	2	6												
Metal working & shops	348	386	144	182	204	204			4	6	4	7	5	2	3		3	4	2	4										
Detail design	174	215	110	85		15	*64	*115									6	4	3	8	2									
Electrical principles	180	162	96	100	56	32	28	30											9		5	6		6						
Interchangeability & tolerances		34		24		10												2												
Thermodynamics & heat transfer	222	233	148	199	46	14	28	20									9	3	6	4		8								
Hydraulics	108	102	90	68	18	15		19									6	6												
Steam & gas turbines	276	323	170	230	50	52	*56	41											8		4		4	13	6	11				
Lifting & transporting machines		116		32				*84												2		8								
Gas dynamics		134		90		16		28												4		5								
Metallurgy		135		90		45														6							3			
Technology of turbine construction	152	70	132	60		10	*20														4	5	8							
Electric power stations		52		52																							4			

Diploma Project ← → Diploma Project

Appendix G (B)—Continued

Appendix G (B)—Continued

Subject	Total, hr.		Lecture, hr.		Laboratory, hr.		Recitation, hr.		Hours per week—per semester																			
									I		II		III		IV		V		VI		VII		VIII		IX		X		XI	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Thermal measurements	72		36		36																4									
Compressors	56	78	42	65	14	13																	6	4						
Automatic control	56	65	42	52	14	13																		4				5		
Fuels & boilers	132		112		20																4		6							
Combustion chambers**	56	70	56	14				*14																	4	5				
Instrument maintenance aircraft gas turbine**		56		48		8																				4				
Heat exchangers**		52		42		10																						4		
Aircraft gas turbines**		65		52				*13																				5		
Economics & administration of industry	100	86	86	86			*14																3		5	4		3		
Safety engineering & fire prevention	42	42	42	32		10																			3	3				
History of mechanics		42		42																								3		
Physical education	136	136					136	136	2	2	2	2	2	2	2	2														
Totals	4350	4960	2380	2713	646	658	1324	1589	36	36	36	36	32	33	29	34	34	34	30	31	25	35	24	28	26	27		27		

* Projects combined with recitation.

** Special courses for aircraft engine option; for other options other courses are substituted.

Electives which may be taken as overload

Numbers in parentheses refer to semesters

0521 (a)	
Physical education & sport (1 to 8)	374 hr.
Engineering drawing (2 to 4)	50
Automobiles (8)	40
Thermal devices & measurements (6)	48
Gas & steam turbines (1)	36
Turbine assembly	40
Maintenance & overhaul of turbines	30
Plant organization	40
Materials (10)	28
Machine design (6/10)	260

0521 (b)	
Physical education & sport (1 to 8)	378 hr.
Hydraulic machines (7)	36
Special topics in mathematics (5)	36
Special topics in metallurgy (6)	20
Internal combustion engines (8)	30
History of technology (9)	28
Vibrations (theory & measurements) (7)	36

Appendix G

C) Automobile Maintenance (1955/56) (1609) (Standard)

Subject	Total, hr.	Lecture, hr.	Laboratory, hr.	Recitation, hr.	Hours per week—per semester									
					I	II	III	IV	V	VI	VII	VIII	IX	X
Principles of Marxism & Leninism	250	160		90	4	3	4	4						↑
Political economy	140	100		40					2	3	2	3		
Foreign language	256			256	2	2	2	2	(2)	(2)	(2)	(2)		
Higher mathematics	378	189	16	173	8	6	5	3						
General chemistry	120	70	50		4	3								
Physics	242	142	80	20	5	5	4							
Descriptive geometry	90	50		40	5									
Machine drawing	170			170	3	3	5	2						
Theoretical mechanics	200	100		100		4	4	4						
Strength of materials	188	102	34	52			6	5						
Theory of mechanisms & machines	154	102	16	36				4	5					
Detail design & lifting machines	183	120	18	45*					6	5				
Shops	166		166		3	4		3						
Technology of metal working	199	166	33			4	3		2	3				
Metallurgy and hot-working	102	68	34					3	3					
Tolerances & technical measurements	60	30	30							4				
Electrical engineering & equipment	169	97	58	14*						4	5	3		
Heat engineering	132	81	51						4	4				
Hydraulics & hydraulic machines	108	54	36	18					4	3				
Automobile	239	151	88								5	4		
Automobile engines	202	132	42	28*						6	8			
Fuel, lubricants	70	40	30								5			
Automobile transportation	78	78										3	3	
Automobile maintenance techniques	91	65	26									3	4	Diploma Project

Appendix G (C)—Continued

Subject	Total, hr.	Lecture, hr.	Laboratory, hr.	Recitation, hr.	Hours per week—per semester									
					I	II	III	IV	V	VI	VII	VIII	IX	X
Assembly & overhaul of automobiles	161	107	54								5	3	4	
Economics of transportation	65	55		10								5		
Organization of motor pools	65	65											5	
Technical buildings	39	39											3	
Automobile highways	28	28									2			
Safety engineering & fire prevention	39	30	9										3	
Physical education	136			136		2	2	2						
Totals	4520	2421	871	1228	36	36	35	32	26	32	32	24	22	

Parentheses mean can be taken as an extra load
* Projects combined with recitation.

Electives as overload
Numbers in parentheses indicate semesters

Sport (1 to 8)	376 hr.
Highway code (5)	20
Motorcycles (6)	20
Tractors (6)	20
Gas turbines (7)	20
History of engineering (8)	30
Prospects of development of autos	26

Course projects
Graphical strength of materials
Hydraulics
Mechanisms & machines
Detail design
Electrical equipment
Automobile engine
Automobile design
Organization of motor pools
Overhaul motor shop
Maintenance

Appendix G

D) Hydro-technical Construction of River Works and Hydro-electric Stations (1955–56) (1203) (1203a)
(a) Construction faculties (standard)
(b) Moscow Construction Engineering Institute } 5 years

Subject	Total, hr.		Lecture, hr.		Laboratory, hr.		Recitation, hr.		Hours per week—per semester																	
									I		II		III		IV		V		VI		VII		VIII		IX		X	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Principles of Marxism & Leninism	250	250	160	160			90	90	4	4	3	3	4	4	4	4											↑	↑
Political economy	140	140	100	100			40	40									2	2	3	3	2	2	3	3				
Foreign language	256	256					256	256	2	2	2	2	2	2	2	2	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)				
Higher mathematics	394	394	190	190	16	16	188	188	8	8	6	6	5	5	4	4												
General chemistry	120	120	70	70	50	50			4	4	3	3																
Physics	224	224	124	124	80	80	20	20	4	4	5	5	4	4														
Descriptive geometry	104	104	52	52			52	52	4	4	2	2																
Drafting & drawing	120	120			120	120			4	4	3	3																
Geodesy	104	104	52	52	52	52			4	4	2	2																
Theoretical mechanics	184	184	100	100			84	84			4	4	4	4	3	3												
Strength of materials	188	188	102	102	54	54	32	32					6	6	5	5												
Construction mechanics & theory of elasticity	216	216	108	108			108	108									5	5	6	6	3	3						
Construction materials & metals	136	136	64	64	72	72					4	4	4	4														
Electrical engineering & equipment	96	96	64	64	32	32									6	6												
Machine design*	252	252	132	132	120	120									3	3	9	9	3	3								
Organization of construction projects*	238	238	154	150	56	50	28*	38*											6	4	3	4	4	4	4	5	Diploma Project	Diploma Project
Architecture	54	54	34	34	10	10	10*	10*									3	3										
Engineering geology	90	90	45	45	45	45											5	5										
Mechanics of water tables	98	98	70	70	14	14	14*	14*											3	2	4	5						
Engineering construction (steel)	70	70	46	46	10	10	14*	14*												5	5							

Appendix G (D)—Continued

Subject	Total, hr.		Lecture, hr.		Laboratory, hr.		Recitation, hr.		Hours per week—per semester																	
									I		II		III		IV		V		VI		VII		VIII		IX		X	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Engineering construction (cement)	98	112	88	80	10	10		22*												2	7	6						
Engineering construction (wood)	42	42	32	32	10	6		4															3			3		
Hydraulics	194	194	88	88	64	64	42*	42*							3	3	5	5	4	4								
Hydrology & hydrometry	68	68	44	44	14	14	14*	14*									3	3	1	1								
Hydraulic machines		56		42		7		7														4						
Hydro-electric stations & machines	168		112		28		28														4		6		2			
Hydro-technical installations	196		126		28		42*												4		4		6					
Economics of water resources	70	70	60	60			10	10															5			5		
Waterways and ports	70	70	56	54	14	10	0	6																5	5			
Drainage & irrigation	70	70	70	54	0	10	0	6																	5	5		
Safety engineering & fire prevention	42	42	30	30	12	12																		3	3			
Electives**	70		70																						5			
Subjects in desired option***		364		270		56		38*														8		12		6		
Physical education	136	136					136	136	2	2	2	2	2	2	2	2											↓	↓
Total	4558	4558	2439	2417	771	770	1348	1371	36	36	36	36	31	31	32	32	32	32	30	30	32	32	27	27	24	24		

Appendix G (D)—Continued

* (Moscow Institute has additional thermodynamics and some research.)

** General electives (these are also offered as overloads at Moscow Construction Institute)

History of engineering	28 hr.	Non-stationary regimes in hydro-installation	28 hr.
Development of hydro-installation	28	Specific problems of hydraulic power installation	28
Applied thermodynamics	28	Specific problems of hydraulics of variable mass	28
Testing of hydro-installation	28	Specific problems of mechanization of hydraulics	28
Development of hydro-construction	28	Maintenance of hydraulic installations	28

*** Options at Moscow Construction Institute

1) River hydro-technical installations
   - Hydro-technical installations — 238 hr. (182 + 28 + 28*)
   - Hydro-electrical stations — 126 hr. (88 + 28 + 10)
2) Hydro-electric stations
   - Hydro-electric stations — 196 hr. (140 + 28 + 28*)
   - Hydro-technical installations — 126 hr. (88 + 28 + 10)
   - Electrical equipment of stations — 42 hr. (30 + 6 + 6)
3) Hydro-mechanization of earthworks
   - Hydro-mechanization — 140 hr. (98 + 28 + 14)
   - Hydro-technical installations — 126 hr. (88 + 14 + 24*)
   - Hydro-electric stations — 98 hr. (70 + 14 + 14)

Sample term projects for courses in all options

Exercises in strength of materials	Cement hydraulic construction project
Exercises in applied mechanics	Project on foundations and seepage
Architecture project	Steel construction project
Earthworks project	Reinforced concrete project
Hydraulics project	Wood construction project
Hydrometry project	Design of a lock on a river
Cement hydraulic construction project	
Project on organization of a construction project	

Special term projects (a) (Construction Faculties)

Project on flow regulation	Design of electric station
Project on cement platen	Elective design
Project on platen from local materials	

Special term projects (b) (MCI)

Option 1

Cement platen design	Flow regulation for power project
Local material platen design	Design of electric station
Design of river installation	

Option 2

Flow regulation for power project	Platen made out of local materials
Design of electric station	Cement platen design
Equipment of electric station	

Option 3

Mechanized canalization design	Platen made out of local materials
Equipment for canalization	Regulation of flow and station design
Cement platen design	

Appendix G

E) Inorganic Chemistry (1955/56)
(a) Chemical engineering institutes (0803)
(b) All Union Correspondence Polytechnic Institutes (0803a) (VZPI)

Subject	Total, hr.		Lecture, hr.		Laboratory, hr.		Recitation, hr.	No. of papers	Hours per week—per semester																							
									I		II		III		IV		V		VI		VII		VIII		IX		X		XI	XII		
	a	b	a	b	a	b	a	b	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	b[2]	b[2]		
Principles of Marxism & Leninism	250	60	160	60			90	4	4	(1) 15	3	(1) 15	4	(1) 15	4	(1) 15															↑	↑
Political economy	140	40	100	40			40	3									2	10	3	(1) 10	2	(1) 10	3	(1) 10								
Foreign language	252	60				60	252	8	2	(1) 8	2	(1) 8	2	(1) 8	2	(1) 8	(2)	(1) 8	(2)	(1) 8	(2)	(1) 6	(2)	(1) 6								
Higher mathematics	328	90	164	40	10	50	154	10	8	(3) 24	7	(2) 22	4	(3) 22		(2) 22																
Physics	232	90	132	20	70	70	30	6		(1) 20	6	(1) 20	4	(2) 25	4	(2) 25																
Descriptive geometry & drafting	208	46	36	16		30	172	5	8	(2) 15	4	(1) 11		(1) 10		(1) 10																
Technology of metals	84	22	36	10	12	12	36	2									2	(1) 11	4	(1) 11												
Theoretical mechanics	100	40	60	20		20	40	3			4		2	(1) 10		(1) 10		(1) 10		10												
Strength of materials	100	36	50	16	20	20	30	3					2		4	(2) 18		(1) 18														
Detail machine design	146	44	102	30	0	14	*44	2							2		5		2			(0) 17		(1) 17		(1) 10						
Inorganic chemistry	222	130	100	30	122	100		4	7	(2) 65	6	(2) 65																				
Analytical chemistry	290	180	30		260	180		2					9	(1) 50	8	50		40		(1) 40												

Appendix G (E)—Continued

Subject	Total, hr.		Lecture, hr.		Labora-tory, hr.		Reci-tation, hr.	No. of pa-pers	Hours per week—per semester																					
									I		II		III		IV		V		VI		VII		VIII		IX		X		XI	XII
	a	b	a	b	a	b	a	b	1 a	2 b	1 a	2 b	1 a	2 b	1 a	2 b	1 a	2 b	1 a	2 b	1 a	2 b	1 a	2 b	1 a	2 b	1 a	2 b	2 b	2 b
Organic chemistry	262	114	100	22	162	92		4					4		4		7	(1) 39		(1) 39		(1) 18		(1) 18			Diploma Project			Diploma Project
Physical chemistry	264	86	110	16	154	70		4									8		10			(2) 43		(2) 43						
Colloidal chemistry	72	20	32		40	20		1													4					(1) 20				
Thermodynamics	138	38	86	14	24	24	*28	3							3		5	(2) 19		(1) 19										
Electrical engineering	132	54	68	18	40	36	24	4									4	(2) 27	5	(2) 27										
Chemical technology	132	36	102	16	30	20		3											5		4					(2) 18		(1) 18		
Processes & application in chemical engineering	212	122	102	50	72	72	*38	4											4		8		2			(2) 61		(2) 61		
Automation of chemical plants	72	10	36		36	10		1													4							(1) 10		
Safety engineering & fire prevention	40	10	30	10	10			1															4						(1) 10	
Economics of chemical engineering	40	20	40	20				1															4						(1) 20	
Administration & organization of plants	60	30	48	30			12	1																	5				(1) 30	
Construction & sanitation	36	10	36	10				1														(1) 10			3					
Theory of chemical processes	54	10	54			10		1													3					(1) 10				

Appendix G (E)—Continued

Subject	Total, hr.		Lecture, hr.		Laboratory, hr.		Recitation, hr.	No. of papers	Hours per week—per semester																							
									I		II		III		IV		V		VI		VII		VIII		IX		X		XI		XII
	a	b	a	b	a	b	a	b	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	a[1]	b[2]	b[2]	b[2]
Inorganic chemical technology	434	266	204	46	230	220		5																		(2)		(2)	(1)		
																					4		17		16	58		58	150		
																													(2)		
Plant equipment	36	20	36	20				2																	3				20		
Crystallography & mineralogy	36		36					1													2					(1)					
Physical education	136						136		2		2		2		2																	
Electives**	36	20	36	20				1																	3				(1) 20		
Totals	4544	1704	2126	574	1292	1130	1126	90	31		34		33		33		33		33		31		30		30						
									For "b" cols.				For "b" cols.				For "b" cols.				For "b" cols.				For "b" cols.				For "b" cols.		
									18 papers 106 lecture hr. 182 laboratory hr.				18 papers 70 lecture hr. 210 laboratory hr.				12 papers 72 lecture hr. 200 laboratory hr.				19 papers 104 lecture hr. 186 laboratory hr.				16 papers 92 lecture hr. 232 laboratory hr.				7 papers 130 lecture hr. 120 laboratory hr.		

* Projects combined with recitation.

** Electives

Physico-chemical analysis	60 hr.
Corrosion & metal protection	24 hr.
History of engineering	40 hr.

Numbers in parentheses mean the number of term papers to be sent to Moscow.

1. Hr. per week.
2. Hr. per semester.

Appendix G

F) Mechanics—Moscow State University (1958/59) (course number not available)

Subject	Total, hr.	Lecture, hr.	Laboratory, hr.	Recitation, hr.	Hours per week—per semester								
					I	II	III	IV	V	VI	VII	VIII	IX
Principles of Marxism & Leninism	224	144		80	3	3	4	4					
Political economy	140	100		40					2	2	2	5	
Dialectical materialism	140	80		60							2	3	5
Foreign language	204			204	4	4	2	2					
Analytical geometry	188	102		86	6	5							
Mathematical analysis	460	240		220	8	8	7	4					
General astronomy	70	70			4								
Higher algebra	136	68		68	4	4							
Differential equations	136	68		68			4	4					
Theoretical mechanics	334	216		118		6	4	4	3	3			
Physics	310	170	104	36			5	4	5	2	2		
Differential geometry	70	54		16			4						
Functions of a complex variable	108	72		36					6				
Equations of mathematical physics	136	100		36						4	4		
Theory of probability	56	42		14									4
Variational calculus	36	36							2				
Hydro-aeromechanics	134	134						2	3	3			
Theory of elasticity & plasticity	100	100							3	3			
Gas dynamics	60	60									2	2	
Vibration theory	36	36									2		
Strength of materials	64	32	32					4					
History of mechanics	56	56											4
Electives*	356	180		176					2	4	6	6	6
Laboratory courses	436		436						4	6	8	8	2
Physical education & sport	136			136	2	2	2	2					
Totals	4126	2160	572	1394	31	32	32	30	30	27	28	24	21

Extra subjects

Sports—440 hr.; foreign language—160 hr.; thesis for full 10th term.

Appendix G (F)—Continued

* List of Electives (see # 23):

I. *Theory of elasticity*

1. Plates and shells
2. Statics and dynamics of disturbances
3. Wave propagation in elastic media
4. Plane problems in elasticity
5. The contact problem in elasticity
6. Variational methods in elasticity
7. Optical methods of stress investigation
8. Stability of elastic systems
9. Vibrations of elastic systems
10. Propagation of non-linear waves
11. Methods of measurement of mechanical waves
12. Advanced strength of materials
13. Theory of elasticity of anistropic materials
14. Theory of strength

II. *Aero-mechanics & hydro-mechanics*

1. Thin wing theory
2. Hydrodynamical methods in function theory
3. Wing and propeller theory
4. Advanced gas dynamics
5. Spherical dynamics of the stability of flight vehicles
6. Kinetic theory of gases
7. Flight dynamics
8. Turbulence theory
9. Experimental aeromechanics
10. Aero-mechanics of bodies of variable mass
11. Theory of reactive propulsion
12. Fransonic flow
13. Applied gas dynamics
14. Unsteady gas motion
15. Oscillations of bodies in air streams
16. Turbine theory
17. Theory of cavitating motion
18. Plane problems in hydromechanics
19. Theory of flow of mixtures and suspensions
20. Theory of acoustic waves
21. Hydromechanical applications to meteorology
22. Theory of motion of viscous fluids
23. Hydraulics
24. Jet theory
25. Mixed problems
26. Filtration of liquids and gases
27. Theory of wave motion

III. *Applied mechanics*

1. Vibration theory
2. Regulation theory
3. Dynamics of machines
4. Synthesis of mechanisms
5. Applied gyroscope theory
6. Gyroscopic stabilization
7. Electromechanics and electrical machines
8. Computing mechanisms
9. Operational and metric calculation in vibration theory
10. Measurement of mechanical quantities
11. Vibrations of shafts
12. Non-linear vibrations
13. Statistical methods in the theory of oscillations and regulations
14. Dynamics of guided flight
15. Theory of mechanisms
16. Model theory and similarity
17. Following systems

Appendix G (F)—Continued

IV. *Theoretical mechanics*

1. Stability of motion
2. Integration of the dynamical equations
3. Periodic solutions of mechanics problems
4. Mechanics of bodies of variable mass
5. Motion of bodies about fixed points
6. Dynamics of non-holonomic systems
7. Principles of mechanics of threads
8. Methods of teaching mechanics
9. Relativistic mechanics
10. Geometrical theories of body motion
11. Integral invariants
12. History of mechanics in Russia and the USSR
13. The philosophical basis of mechanics
14. History of hydro-aero-mechanics
15. History of elasticity

V. *Wave propagation dynamics*

1. Propagation of elasto-plastic waves
2. Theory of ultrasonic waves
3. Theory of surface waves in liquids
4. Theory of solid impact
5. Thermodynamics
6. Shock waves and detonations

VI. *Chair of the theory of plasticity*

1. Plane problems in plasticity
2. Metal working
3. Physics of metals
4. Theory of plasticity I and II
5. Creep of metals
6. Visco plastic flow
7. Stability beyond the elastic limit

Notes: 1. The naming and scope of elective and faculty courses is determined every year by the Council of the Faculty according to recommendations by the chairs. The outlines (programmy) of these courses are examined and validated by the Council of the Faculty.

2. An elective is given only to groups of 12 or more students.

Appendix H

Course Schedules in Mathematics

A. Moscow Higher Technical School (Baumann)

Mathematics MVTU—1958–59; First Semester, 16 wk., 126 hr.

32 Lectures—64 hr.	*32 Recitations—62 hr.*
1. Functions	1. Inverse trigonometric functions; principal values; plots of $\sin^{-1} x$, $\tan^{-1} x$
2. Vectors: addition; multiplication by a scaler; orthogonal coordinates in 2, 3 dimensions; projection of a vector, length of a vector, direction cosines	2. Plots of functions
3. Functions	3. Vectors
4. Distance between points in 2, 3 dimensions; division of a segment in a given ratio in space and the plane	4. Functions
5. Limits and infinitesimals; conditions for the existence of limits	5. Distance between points and division of a segment
6. Center of gravity of a system of material points in space and the plane. Equation of a straight line	6. As above
7. The number l and $\lim_{x \to 0} \frac{\sin x}{x}$	7. The straight line
8. The straight line	8. Limits
9. Theorems on infinitesimals and limits	9. The straight line
10. The straight line; neighborhoods	10. As above
11. Infinitesimals of various orders	11. The straight line; neighborhoods
12. The ellipse and the hyperbola (simplest cases)	12. Limits and infinitesimals of various orders
13. Asymptotes; continuity	13. Simplest equations of parabola, hyperbola, and ellipse
14. The parabola (simplest case); translation of axes Equations: $y = ax^2 + bx + c$; $Ax^2 + Cy^2 + 2Dx + 2Ey + F = 0$	14. As above
15. Speed; tangent; derivative; differential	15. Asymptotes; sample graphs and study of asymptotes; equation

Appendix H (continued)

16. Rotation of axes; equations $xy = C$, $y = \frac{ax + b}{cx + d}$	$\left(\frac{x - x_0}{a}\right)^2 \pm \left(\frac{y - y_0}{b}\right)^2 = 1$
17. Rules and formulas of differentiation	17. Equations $\left(\frac{x - x_0}{a}\right)^2 \pm \left(\frac{y - y_0}{b}\right)^2 = 1$; $(x - x_0)(y - y_0) = C$
18. General equation of 2nd degree curves; polar coordinates	18. Quiz: straight line and curves
19. Differentiation formulas	19. Colloquium: limits and derivatives
20. Special curves—cycloids, spirals, etc.	20. Differentiation technique
21. Differentiation of implicit and parametrically defined functions	21. Exercises in differentiation
22. Derivative and differential of 2nd and higher order	22. As above
23. Theorems of Rolle and LaGrange	23. Higher order differentials and derivatives
24. L'Hopital's rule and Taylor's formula	24. Tangents and normals
25. Study of increasing, decreasing and stationary characteristics functions	25. Quiz (1 hr.) differentiation; (problem on curves handed out); L'Hopital's rule (1 hr.)
26. Convexity, concavity, and inflexion points	26. Graphs
27. Complete study of functions and construction of their graphs	27. Graphs
28. Determinants of 2nd and 3rd order	28. As above
29. Systems of linear equations	29. Graphs; problem handed back
30–32. Review	30–32. Review

Mathematics MVTU—1957–58: Second Semester, 15 wk.

30 Lectures—60 hr.	*30 Recitations—60 hr.*
1. Coordinates and decomposition of a vector; length of a vector in space; direction cosines	1. Exercises in integration
2. Indefinite integral; properties; tables	2. As above

Appendix H (continued)

3. Scalar differentiation; angle between vectors; vector differentiation; area of a triangle	3. Vectors
4. Change of variable of integration; integration by parts	4. Exercises in integration
5. Mixed differentiation of 3-dimensional vectors; volume of a parallelopiped; coplanar conditions	5. Vectors
6. Integration of rational functions	6. Exercises in integration
7. Equations of the plane	7. Vectors
8. Integrals reducible to integrals of rational functions	8. Exercises in integration
9. Equations of a straight line	9. Areas
10. Definite integral as the limit of a sum	10. Quiz—vectors
11. Straight line and plane	11. The straight line
12. Properties of definite integrals; mean value theorem	12. Exercises in integration
13. 2nd order surfaces; sphere, cylinder, ellipsoid, etc.	13. The plane and straight line
14. Formula of Leibnitz-Newton; change of variable and integration by parts	14. Exercises in integration
15. Curvature of a plane curve	15. Exercises in integration
16. Geometrical applications of definite integrals	16. Quiz—indefinite integrals
17. Variable vectors; curves in space	17. Areas
18. Geometrical applications of definite integrals	18. Calculation of definite integrals
19. Curvature and twist of a curve in space; Fresney's formula	19. Geometrical applications
20. Improper integral	20. As above
21. Physical applications of definite integrals	21. Geometrical applications
22. Approximate calculation of definite integrals	22. As above
23. 1st order differential equations	23. Colloquium: definite integrals

Appendix H (continued)

24. As above	24. 1st order differential equations
25. 1st order differential equations	25. Separable, homogeneous and linear differential equations
26. 2nd order differential equations reducible to 1st order	26. As above
27–30. Review	27. Bernoulli differential equations 28–30. Review

Mathematics MVTU—1958–59; Third Semester, 16 wk., 64 hr.

16 Lectures—32 hr.	*16 Recitations—32 hr.*
1. General properties of 2nd order linear differential equations without right side; Wronskian Formula of Ostrogradski-Liouville; theorem of Ostrogradski; integration when one solution is known	1. Integration of 2nd order equations whose order may be lowered
2. Linear 2nd order differential equations with a right hand side. Solution of non-homogeneous equation as a sum of solutions, theorem of superposition; variation of parameters	2. (See 1)
3. Linear 2nd order differential equations with constant coefficients without right hand side; characteristic equation; three classes of roots; method of selection of particular solutions for linear 2nd order differential equations with right hand side	3. (See 1)
4. Enter equations; linear equation of order "h" (generalization of result without proof)	4. Linear equations with constant coefficient
5. Concept of systems of linear equations; problems of mechanics and physics which lead to linear equations	5. (See 4)
6. Functions of several variables; partial derivatives of first and higher order	6. Colloquium on differential equations
7. Total differential; its invariance; differentiation of complex and implicit functions	7. Domain of existence; trajectories; partial derivatives
8. Multiple differentiation of implicit functions; higher order differentia-	8. Quiz—2nd order differential equations

Appendix H (continued)

tion; the formula

$$\Delta z = dz + \frac{d^2z}{2!} + \frac{d^3z}{3!} + \cdots$$

(without proof); Taylor's formula

9. Derivatives in a given direction; gradients and their properties	9. Total differential of implicit functions
10. Tangent surface and normal to a surface; stationary points (necessary conditions)	10. Gradient; homework problem on surfaces handed out
11. Stationary points (sufficient condition); conditional stationary points	11. Tangent surface
12. Properties of total differentials; integration of total differentials; differential equations with total differentials	12. Extrema
13. Line integrals	13. Total differential equations
14–15. Line integrals	14–15. Line integrals
16. Review	16. Review

Mathematics MVTU—Fourth Semester, 16 wk., 46 hr.

13 Lectures—26 hr.	*10 Recitations—20 hr.*
1. Scaler and vector fields; formula of Green-Ostrogradski; line integral in space; circulation	———
2. Surface integral; vector flux through a surface; formula of Gauss-Ostrogradski; vector divergence	———
3. Formula of Stokes-Ostrogradski; vortex-curl; solenoidal and potential fields	Triple integrals; surfaces by means of line integrals
4. Numerical series; manipulation; necessary conditions for convergence	Surface integrals; relations with line integrals
5. Sufficient conditions for convergence of series of positive terms	Series (numerical)
6. Alternating series; Leibnitz's lemma; structure of absolutely and conditionally convergent series	As above
7. Power series; Abel's theorem; interval of convergence	Functional series; power series; interval of convergence

Appendix H (continued)

8. Properties of power series	Power series; expansion of functions into power series
9. Taylor and MacLaurin series; expansion of elementary functions	Applications of power series
10. Application of power series to the solution of various problems of mathematical analysis	As above
11. Trigonometric series; Euler-Fourier coefficients; Dirichlet theorem (no proof)	Trigonometric series
12. Finite trigonometric series; arbitrary period	Trigonometric series (consultations) Problem on series
13. Problem of small oscillations of a plate	———
Review	Oral review; examination

B. Frunze Polytechnic Institute

Summary of Course Schedule in Mathematics

1. Analytical geometry, vector algebra, determinants	77 hr.
2. Introduction to analysis	40
3. Differential calculus of functions of one variable	68
4. Integral calculus of functions of one variable	64
5. Differential calculus of functions of several variables	20
6. Integral calculus of functions of several variables	24
7. Series	36
8. Differential equations	36

Appendix I

List of Study and Consultation Points

All-Union Extension Polytechnic Institute

1. Angarsk (Irkutsk region)
2. Vorkuta
3. Voronezh
4. Zlatoust
5. Alma Ata (Kazakh SSR)
6. Kaliningrad (Moscow region)
7. Krasnodar
8. Krasnoyarsk
9. Kuibyshev
10. Magadan
11. Moscow
12. Novosibirsk
13. Norilsk (Krasnoyarsk region)
14. Orsk (Orenburg region)
15. Podolsk (Moscow region)
16. Rostov on Don
17. Riazan
18. Sarapul (Udmurtsk ASSR)
19. Saratov } Different industrial locations
20. Saratov }
21. Stalingrad
22. Stalinogorsk (Moscow region)
23. Sterlitamak
24. Tashkent
25. Tula
26. Taganrog
27. Ulan-Ude (Buriat-Mongol ASSR)
28. Chirchik (Tashkent region of Uzbek SSR)
29. Cheboksari
30. Shelkovo (Moscow region)
31. Yaroslavl

Appendix J

Principal References on Higher Education in the Soviet Union

1. Counts, George S. *The Challenge of Soviet Education.* New York, McGraw-Hill Book Co., Inc., 1957. 330 p.

   Based on years of study of the Soviet educational scene, this book presents in broad outline the basic features of Soviet education, and provides a guide to interpretation of fragmentary and comprehensive reports appearing in English on what the schools in the Soviet Union are doing.

2. DeWitt, Nicholas. *Soviet Professional Manpower: Its Education, Training, and Supply.* Washington, National Science Foundation, 1955. 400 p. Available from the U. S. Government Printing Office, Washington 25, D. C.

   This research study deals with the general Soviet educational system and more specifically with numbers of scientists and technicians being trained in the USSR. Data from Soviet source materials are compiled and analyzed.

3. Korol, Alexander G. *Soviet Education for Science and Technology.* New York, Technology Press of Massachusetts Institute of Technology, John Wiley & Sons, Inc., 1957. 513 p.

   Documented and based largely on available original source materials, this work on the scientific and technical aspects of the Soviet educational system resulted from 5 years of research plus data accumulated over 11 years at MIT Center for International Studies. It provides an introduction to lower school programs and deals with organization, administration, curriculums, and teaching of university level programs, presenting such data as numbers of majors and hours of courses. Translations of syllabuses, articles, and textbook analyses are included.

4. U. S. Congress. Joint Committee on Atomic Energy. *Engineering and Scientific Manpower in the United States, Western Europe and Soviet Russia.* Washington, U. S. Government Printing Office, 1956. 85 p., diagrams, tables (84th Congress, 2nd Session).

   Information on the availability of engineers and scientists in the U. S., 17 Western European countries, and the USSR with student enrollments, graduation rates, and qualitative assessment is presented for the most part through statistical tables and charts.

5. U. S. Department of Health, Education, and Welfare. Office of Education. *Education in the USSR.* Washington, U. S. Government Printing Office, 1957. 226 p. (Bulletin 1957, No. 14.) Available from the U. S. Government Printing Office, Washington 25, D. C.

   A general description is given of Soviet educational programs at the various levels. The political and historical climate in which Soviet schools have developed is summarized for the nonspecialist. Basic methods and problems of teacher training are discussed. Official Soviet source materials were used, and data on organization, enrollments, and courses are presented in chart form.

6. Ministerstvo vysshego obrazovaniia SSSR. *Vysshaia shkola: Osnovnye postanovleniia, prikazy i instruktsii* (The Higher School: Basic regulations, decrees, and directives). L. I. Karpov and V. A. Severtsev, *eds.* Moskva, Gosudarstvennoe izdatel'stvo "Sovetskaia Nauka," 1957. 656 p.

   This official statement on the legal status of higher education in the USSR supplements materials compiled earlier by M. Movshovich, N. I. Boldyrev, and A. M. Danev. Gives data on organization, admissions, subject majors, textbooks, industrial utilization of specialists, research organization, wages, benefits and welfare, and financial control.

7. *Spravochnik dlya postupayuschikh v vysshaya uchebnie zavedeniya* (Handbook for Those Entering Higher Educational Institutions). Moscow: "Sovetskaya Nauka," 1958. 272 p.

POINTS OF INTEREST AT THE ANNUAL MEETING

The Carnegie Library of Pittsburgh, located between the University of Pittsburgh and Carnegie Institute of Technology campuses, is part of the building which houses the Museum and Art Gallery. It contains approximately 1,500,000 volumes. The technology section is considered to be one of the very best in the country, covering almost all aspects of science and engineering. The library contains a special section on Western Pennsylvania history. On the main floor is a large children's library and two unusual "browsing" rooms, one on international affairs and one on current literature. The library is open daily, except Sunday, from 9:00 a.m. to 10:00 p.m., and on Sundays, 2:00 p.m. to 6:00 p.m.

The Mellon Institute of Industrial Research, located adjacent to the University of Pittsburgh campus, is perhaps the country's outstanding cooperative industrial research laboratory, where the idea of sponsored cooperative industrial research was first developed and put into practice. The present building was opened in 1934 and contains some very unusual features. Of Greek architecture, it has around the outside over 60 Indiana limestone columns which are about 60 feet high and are the largest monolithic columns in the world. The Institute contains a large lecture hall, an excellent and beautiful library of books on science and engineering. Something over 150 industrial research projects are in operation there at the present time.

ENGINEERING AND SCIENTIFIC EDUCATION CONFERENCE PROCEEDINGS

Copies of the proceedings of the Conference on Engineering and Scientific Education may still be obtained from the Scientific Manpower Commission (1507 M Street, N.W., Washington 5, D. C.). This 100-page booklet contains the papers presented at the conference in Chicago in the fall of 1957. Four papers deal with engineering and scientific educational problems abroad; three analyze the domestic situation; and five deal with specific solutions of the problems confronting our departments of engineering and science in institutions of higher learning.

ASEE had an active part in planning this conference and was one of its co-sponsors. The booklet provides a thoughtful approach to problems that will confront departments of engineering and science for some time to come. The Scientific Manpower Commission will supply one copy without charge to college and university officials and department heads. Additional copies may be obtained for $1.00 each.